



OPERATIVE ENDOSCOPIC & MINIMALLY INVASIVE SURGERY

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Edited by

Daniel B. Jones

Steven D. Schwartzberg



Operative Endoscopic and Minimally Invasive Surgery



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Operative Endoscopic and Minimally Invasive Surgery

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Foreword

Logic will get you from A to B. Imagination will take you everywhere.

Albert Einstein

When Dan and Steve asked me to write the Foreword for this book, I looked at the book's outline and had three observations:

- It is an enormous honor to add a Foreword to this monumental work, *Operative Endoscopic and Minimally Invasive Surgery*, with its 120 chapters covering the minimally invasive and endoscopic procedures with contributions from 241 authors.
- The chapter authors represent the brightest stars in the firmament for every segment of minimally invasive operative procedures. I know almost every one and would trust them to make surgical decisions for me if needed. Many of them are close personal friends. Wrangling that many surgical superstars will be an interesting process.
- I hope the section on hernia repair is the best one, because carrying this book will improve business.

In my experience, this is the first textbook that seriously addresses COST (which conversion factors are

used?), a factor that has become part of the surgical decision-making process. I congratulate the authors for this dive into reality. It is amazing for me, having participated in the (r)evolution of endoscopic surgery for more than 60 years, performing some of the procedures for decades, how much our thinking has evolved. One can only imagine the names of the chapters in the second edition of the text in 10 years.

When, after 3 years of hard work, I was able to publish a compendium of *Endoscopy* (Appleton Century Croft, New York) in 1976 with 60 chapters, and it was considered a “complete guide.” It covered the basic principles of the physics, optics, electronics, video, communications, as well as every procedure known at that time. We had 52 authors whose writings were interpreted as “modern data” or regarded by many as a *utopian* view of surgery.

There is no utopia. We keep changing the definition for the better. We should be grateful that Daniel Jones and Steve Schwartzberg's imagination and integrity are unlimited, and these 241 authors will set the bar even higher. Good!

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Preface

Celioscopy, peritoneoscopy, or laparoscopy as it has been termed has been around in its earliest inception for at least 100 years. The era minimally invasive surgery exploded after the first videoscopic laparoscopic cholecystectomies were presented at Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and the American College of Surgeons (ACS). It became obvious pretty quickly that patients benefited of smaller scars, less pain, less intrusion, and faster recovery. Almost overnight, surgeons began to apply minimally invasive approaches to more and more operations. Today, laparoscopy is the standard approach for most diseases of the colon, hernia, spleen, and stomach. For more complex procedures, robotic-assisted surgery has made operations, such as the reconstruction after pancreatic head resection, more precise than perhaps even open surgery.

The flexible endoscope, once the domain of the surgeons, is returning home in part as advances in therapeutic endoscopy change the face of GI tract surgery. No longer can a GI surgeon afford not to be proficient with this tool. Surgeons are performing Natural Orifice Endoscopic Surgery (NOTES), transanal procedures including Transanal Minimally invasive Surgery (TAMIS, TEMS), and are performing endoscopic mucosal/submucosal dissection and resection (ESD, EMR). The flexible endoscope is a tool of the modern general surgeon well beyond simple screening applications.

Operative Endoscopic and Minimally Invasive Surgery is the first major textbook to describe new and potentially better approaches to old operations by experts. The chapters are concise and emphasize technique. The color artwork rivals other leading atlases. One feature that makes this book particularly valuable is the expert commentary that critiques the authors' preoperative assessment, operative approach, and outcomes. The reader can quickly understand the operative pearls and potential challenges to a given operative procedure.

We think another appeal of this book is the beautiful classic and contemporary art. Medicine and Surgery evolved as surgeons learned anatomy. Historical paintings have captured the first used operative tools, ether anesthesia, and apprentice model of teaching in operative theaters. Many thanks to Cara Jordan, who curated this collection. In *Operative Endoscopic and Minimally Invasive Surgery*, we have sought to bring the replicas of the art of surgery over time to the reader. We hope to capture the imagination and creativity of all our readers.

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Minimally invasive surgery in the modern health care environment



Joe Wilder, *Operating Team*, 1987. Giclée print, 24 x 20 inches. (Photo courtesy the Joe Wilder Collection.)

There are few images that visualize the inner workings of the operating room with its technological advances and yet profoundly intimate and explicit views into the human body. Retired surgeon Dr. Joe Wilder provides a unique glimpse into the process through his paintings, which depict surgeries from the point of view of one of the actors. Peering over the shoulders of the surgeons in this image, we become a part of the operating team. We are given a momentary slice of what that responsibility might look like, even if we cannot experience it ourselves.

While still a practicing surgeon—the chief of surgery at New York’s Hospital for Joint Diseases and a professor of surgery at Mount Sinai Medical School—Dr. Wilder reorganized his schedule to have time every day to devote to art. He became an acclaimed painter alongside his surgical practice, earning accolades from the *New York Times* and prominent critics for his exhibitions and books. In his words, “In my paintings I encapsulated a

half a century as a committed doctor, highlighting the powerful forces and actions which take place daily in a major hospital setting.”

Dr. Wilder’s motivation comes from his belief that surgeons have a responsibility to those who seek their help. He tries to reflect his commitment to patient care in each of his paintings. He says, “Although hospitals have a macabre quality, they remain beacons of hope for the afflicted and suffering. But I see another side, and this is what my paintings depict. I have envisioned such richness and giving where paragons of kindness and love heal. A hospital after all has no equal as a center to alleviate suffering. The countless patients from all walks of life taught me about the beauty of the human spirit.”

Quotes from “Statement by Joe Wilder,” Joe Wilder Medical Art, published 2011, <https://joewilder.webs.com/statementby-joewilder.htm>.

Cost implications in minimally invasive surgery

CHRISTOPHER M. SCHLACHTA AND JANET MARTIN

INTRODUCTION

It is generally accepted that the technology required to perform advanced laparoscopy is more costly than the standard instruments employed for open surgery. However, these added operating room costs are rationalized on the presumption that we will realize downstream mitigation through faster recovery. Even though total hospital costs may remain elevated, we justify this on the basis of an acceptable level of increased costs required to achieve the improved outcomes provided by laparoscopy. We may be willing to pay more for better outcomes, but there is a limit to the amount of extra resources we are willing to commit, especially for relatively small benefits. In this chapter we explore the cost-effectiveness and provide some practical insight into the cost implications of introducing expensive new equipment into the value equation for minimally invasive surgery.

BACKGROUND AND RATIONALE FOR ECONOMIC ANALYSIS FOR MINIMALLY INVASIVE SURGERY

Physicians and surgeons have a moral and ethical responsibility to provide their patients with the best possible care. If one is not concerned with resources, then the choice of which of two possible therapies to offer a patient becomes an exercise in assessing the evidence of effectiveness. For example, if **Therapy A** is more effective than **Therapy B**, then we prescribe **Therapy A** ([Figure 1.1](#)).

We now live in an era of constrained health-care resources, and it is considered irresponsible to ignore cost implications when deliberating the therapeutic options for our patients. Choices must be made about how to provide the best possible care to as many patients as possible, but within a finite set of reserves. The Accreditation Council

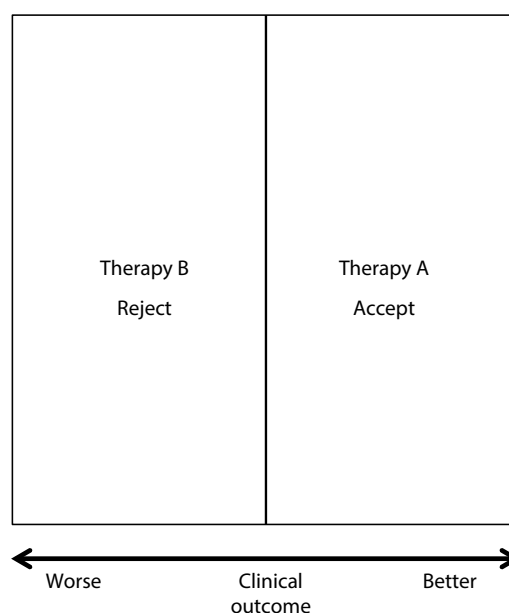


Figure 1.1 Selection of therapy on the basis of effectiveness alone.

for Graduate Medical Education (ACGME) requires that accredited postgraduate programs must incorporate into their curriculum six core competencies. One of these competencies is Systems Based Practice, which includes “considerations of cost awareness and risk-benefit analysis in patient and/or population-based care as appropriate.”¹ Of the seven CanMEDS competencies described by the Royal College of Physicians and Surgeons of Canada, the Manager competency includes a physician who is able to “allocate finite healthcare resources appropriately” and “apply evidence and management processes for cost-appropriate care.”²

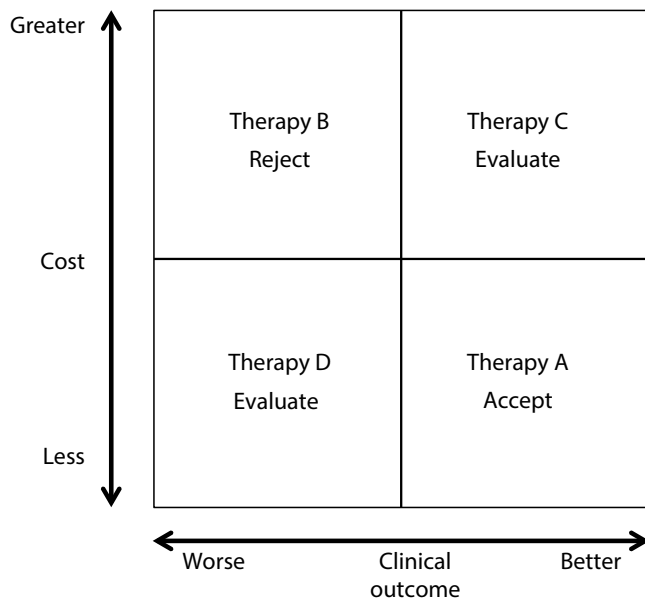


Figure 1.2 Health technology assessment considering trade-off between therapeutic effectiveness and cost.

Once we insert cost considerations into the decision-making process, we subdivide our chart into four conditions across the two dimensions of cost and effectiveness (**Figure 1.2**). **Therapy A** is generally **accepted** because it is better for patients and costs less. This is known as a dominating strategy in health economics, since trade-offs between costs and benefits are not necessary. **Therapy B** is less effective and costs more, which represents a dominating decision to **reject**. We are then left with two quadrants of the chart where the decision-making is not so clear, where competing objectives exist, and trade-offs between costs and effects must be made. **Therapy C**, which is more effective but costs more, requires an evaluation of cost-effectiveness and judgment of how much the funder is willing to pay for that additional benefit. In addition, we have **Therapy D**, which, although clinically inferior, does cost less and warrants evaluation when health-care resources are scarce.

Most economic reports in the surgical literature focus primarily on hospital costs. While these analyses are relevant to the hospital, they are less useful for determining the balance of costs to the health system throughout a patient's lifetime. Increasingly, surgical economic analyses are expanding the perspective of the economic analyses to include not only the hospital costs, but also the total cost of care including follow-up visits in the community (health system perspective or insurer perspective), and in some cases, costs related to loss of time at work or loss of productivity (societal perspective). Depending on the social context, the costs to the patient will also be relevant (patient perspective).

Most will be familiar with the generic value equation for health care, which can be expressed simply as follows:

$$\text{Value} = \frac{\text{Quality}}{\text{Cost}}$$

This can be applied to a new therapy or innovation by considering that the value of that therapy is directly proportional to the quality of care it provides and inversely proportional to the cost of that therapy.³

In order to provide meaningful comparison between two therapies, health economists and by extension health policy makers, in conjunction with political considerations, usually rely on the incremental cost-effectiveness ratio (ICER), typically defined by:

$$\text{ICER} = \frac{\text{Net Cost}}{\text{Net Health Benefit}} = \frac{\text{Cost}_A - \text{Cost}_B}{\text{QALY}_A - \text{QALY}_B}$$

where costs are expressed as the total monetary value of the inputs required, and health benefits are expressed in quality-adjusted life-years (QALYs). QALYs is a metric that is calculated by the extra length of life gained multiplied by the quality of life experienced during the remaining years of life.⁴

MINIMALLY INVASIVE COLORECTAL SURGERY: CASE STUDY

One area in which there is a wealth of data available for analysis occurs in laparoscopic colon surgery. Since the introduction of laparoscopic colon surgery in 1991,^{5,6} early controversy surrounding oncologic safety has made this arguably one of the most scrutinized surgical procedures in history. As a result, a large quantity of high-level evidence is available for analysis of the differences between open and laparoscopic surgery. While we use laparoscopic colon surgery as a focus for the remainder of the chapter, many of the issues raised here will be equally applicable to other minimally invasive procedures and technologies.

Costs of laparoscopic versus open colorectal surgery

A detailed economic evaluation of laparoscopic versus open surgery for colorectal cancer from the UK perspective was reported in two papers by de Verteuil⁷ and Murray.⁸ This analysis modeled cost-effectiveness of laparoscopic versus open surgery over 25 years using the best available evidence at the time. The authors found that laparoscopic colon surgery was dominated by open surgery because it had similar estimated clinical effectiveness but was more costly. They concluded that laparoscopic surgery likely provides short-term quality of life benefits and similar long-term outcomes compared with open surgery but costs an additional £300 (~\$390 USD) per patient. In a threshold analysis, the authors suggested that at £30,000 (~\$39,000 USD) per quality life-year in the United Kingdom, laparoscopic surgery could become cost effective if it provided a benefit of at least 0.01 QALY (essentially the equivalent of 3.5 days of full health over open surgery).

In 2012, Aly and Quayyum published a systematic review of observational studies and clinical trials that reported the costs of laparoscopic and open colon surgery.⁹ Their systematic review of the evidence suggested a gradual decline in the cost gap of laparoscopic surgery over open surgery with time. This decline was partially attributed to the learning curve associated with the introduction of the technology, resulting in higher costs in the near term. This eventually lessened as efficiencies in skills and technology allowed the costs of laparoscopic surgery to approach those of open colon surgery.

In a recent systematic review of the existing randomized and observational studies through 2015, we performed a meta-regression of the cost differential for laparoscopic versus open colorectal surgery and found a significant downward trend over time, which has continued to the present.¹⁰ When we limited our meta-regression to randomized clinical trials, the reduction in cost difference between laparoscopic and open surgery was similar to that found with observational studies (Table 1.1).

In another assessment, we performed a retrospective cost minimization analysis of laparoscopic colon surgery versus open surgery at our institution.¹⁹ Considering hospital costs only, we found the laparoscopic approach was associated with a net cost savings compared to open surgery. Laparoscopic right colectomy costs approximately \$350 less than open surgery (\$10,097.93 CAD versus \$10,444.69 CAD), while laparoscopic sigmoid colectomy cost just \$70 less than open surgery (\$11,076.72 CAD versus \$11,146.56 CAD) for the total hospital stay. This cost saving was achieved in similar fashion to other reports, by offsetting the added cost of operating room technology with downstream inpatient cost savings. Given this hospital cost savings, and associated short-term patient benefits (assuming long-term equivalence in oncologic outcomes), the laparoscopic approach dominates open surgery. However, this analysis also revealed two important considerations: This cost savings was highly sensitive to changes in equipment costs and conversions to open surgery. As a result, the cost savings measured in our institution will not necessarily automatically translate to all settings. Rather, these savings

at our institution were achieved through good judgment and sensible frugality. If a case is converted to open surgery, then one incurs all of the operating room costs of a laparoscopic procedure *in addition to* open surgery, while realizing none of the downstream benefit. Furthermore, the use of a single disposable trocar (sigmoid colectomy) or an additional stapler or energy device (right colectomy) will flip the hospital cost in favor of open surgery. Good judgment on case selection is warranted, and a concerted effort to minimize operative technology cost is necessary. In our institution, and therefore represented in this analysis, is the policy that we use only reusable trocars and instruments. No energy devices or staplers are opened until we are certain that the laparoscopic approach will proceed.

What then can we say about more advanced technology such as single-port surgery or robotic-assisted surgery?

Costs of robotic-assisted versus laparoscopic versus open colorectal surgery

One randomized controlled trial (RCT) ($n = 70$ patients) compared robotic-assisted with laparoscopic right colectomy and found no proven difference in clinical outcomes or oncologic adequacy; however, operating time was increased on average by 65 minutes, and total costs were significantly increased for the hospital, the national insurance payer, and the patients. The extra costs were attributed primarily to the costs of surgery and consumables.¹⁸

A number of systematic reviews and meta-analyses have compared clinical outcomes and costs of robotic colorectal surgery versus laparoscopic or open surgery, including observational studies and the single existing RCT described above. Three separate systematic reviews found robotic colorectal surgery to be associated with longer operation times and increased costs with minimal clinical benefit.^{20–22}

Overall, the evidence to date suggests that the additional costs associated with robotic colorectal surgery, when compared to laparoscopic or open surgery, have not been justified by offsets in downstream costs or by improved clinical outcomes for patients. As a result, many have proposed that

Table 1.1 RCTs of laparoscopic versus open colon surgery providing cost data

Trial	Perspective	Cost		Difference	Percentage (%)
		Open	Laparoscopic		
Braga et al. ¹¹	Hospital	€4826 ^a	€4951 ^a	€125	2.6%
Franks et al. ¹²	Societal	£6631	£6899	£268	4.0%
Janson et al. ¹³	Hospital	€7235	€9479	€2244	31.0%
King et al. ¹⁴	Societal	£6787	£6433	(£353)	(5.2%)
Leung et al. ¹⁵	Hospital	\$9850	\$9729	(\$121)	(1.2%)
Norwood et al. ¹⁶	Operating room	\$9948 AUS	\$10,111 AUS	\$163 AUS	1.6%
Zheng et al. ¹⁷	Hospital	10,228 CNY	11,499 CNY	1271 CNY	12.4%
		Robotic	Laparoscopic		
Park et al. ¹⁸	Societal	\$12,235 USD	\$10,320 USD	(\$1915)	(15.6%)

^a Calculated.

the uptake of robotic surgery should be done only within the context of formal clinical trials to guide future areas for uptake, and to assess whether mitigation of the learning curve, or whether competency-based expertise will allow for achieving acceptable cost-effectiveness.

Costs of single-incision laparoscopic surgery, laparo-endoscopic single-site surgery, natural orifice transluminal endoscopic surgery

Single-incision laparoscopic surgery (SILS), laparo-endoscopic single-site (LESS) surgery, and natural orifice transluminal endoscopic surgery (NOTES) can be considered the extreme of minimally invasive therapy. A number of observational studies have evaluated whether tangible clinical and economic benefits of SILS or NOTES over conventional laparoscopic surgery are found for colorectal surgery. However, the bias inherent in these existing observational studies and meta-analyses of these observational studies preclude definitive conclusions.²³ RCTs with adequate power and follow-up will be required before the incremental cost-effectiveness ratio can be defined. As with most new technologies in the early stages, newly released sophisticated trocars and other dedicated instruments added significant costs to the operating procedure. With increased experience, industry competition, and use of conventional instruments, the costs of technologies for SILS have decreased.²⁴ In a retrospective cost analysis of 260 patients, Stewart et al. reported similar total patient charges (\$34,847 versus \$38,306; $p > 0.05$) or hospital costs (\$13,051 versus \$12,703; $p > 0.05$) for single-site versus conventional laparoscopy, respectively.²⁵ Only a demonstration of improved clinical outcomes in randomized studies and/or reduced costs will ultimately render SILS cost effective compared with conventional approaches.

SPECIAL CONSIDERATIONS FOR COST ANALYSES AND COST-EFFECTIVENESS ESTIMATES IN LAPAROSCOPIC AND ROBOTIC SURGERY

There is great heterogeneity in estimates of the costs for laparoscopic, robotic, and open surgery. This is not unique to colon and rectal surgery. Reasons for this heterogeneity are related to differences in the types of costs incorporated in the estimates provided within these studies, differences in time horizons of the evaluation, and the perspective of the analysis. In general, the studies are in agreement that laparoscopic techniques incur additional technologic costs compared with open surgery. As we continue to push the frontier of what can be accomplished in a minimally invasive fashion, it is important to consider that technology

costs will continue to be the most significant driver when clinical benefits are small.

With the exception of de Verteuil and Murray et al.,^{7,8} all of the costing studies referred to in this chapter were cost analyses only without attempting to calculate the ICER. These provide partial estimates of the comparative cost side of the ICER only, without providing estimates of the incremental benefit, such as QALYs. This is likely due to the paucity of proof of large differences in clinical benefit. As a result, most ICERs, if calculated, would be extremely high, due to the very small size of the denominator. Future economic analyses should focus on providing a full economic perspective, with incremental costs (comprehensively defined) and incremental benefits defined. This will significantly advance our ability to make better decisions about committing resources and improve understanding of the trade-offs and opportunity costs among minimally invasive options for surgery.

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Enhanced recovery programs in minimally invasive surgery

NICOLÒ PECORELLI AND LIANE S. FELDMAN

INTRODUCTION

Improving recovery for patients through reducing surgical trauma is a key goal of minimally invasive surgery. It is well understood that the negative consequences of surgery, including pain, organ dysfunction, catabolism, fluid/salt retention, and sleep disturbances are proportional to the degree of tissue injury and the resulting surgical stress response.¹ The mechanisms of surgical stress are very complex including a systemic inflammatory response mediated by pro-inflammatory cytokines and metabolic changes mediated by endogenous catecholamine and steroid release leading to increased insulin resistance and protein catabolism.² Digestive surgery involves two separate wounds: one in the abdominal wall and one to the peritoneum and viscera, each triggering a systemic neurohumoral response.³ When the major trigger of the stress response is the abdominal wall incision, the benefits of laparoscopy are obvious. When the laparoscopic revolution began in the early 1990s, surgeons were immediately struck by how much better their patients looked after laparoscopic compared to open cholecystectomy. Patients undergoing cholecystectomy, fundoplication, and colonic and bariatric procedures now require hospital stays shorter than 24 hours. These results would be difficult to imagine after open surgery.

But even when the length of stay is short, full functional recovery takes weeks or months.⁴ With colon surgery, full physical recovery is not complete even 2 months postoperatively.⁵ Complications of abdominal surgery remain relatively high,⁶ and complications further delay patient recovery.⁷ Perioperative care is a complex intervention made up of multiple smaller interventions, each of which has the potential to improve or delay patient recovery and influence outcomes. In addition to minimally invasive surgery

(MIS), multiple other interventions are available that reduce metabolic stress through a variety of mechanisms.^{8,9} Some in clinical use include pharmacologic (afferent neural blockade using local anesthetics, glucocorticoids, intravenous local anesthetics, and nonsteroidal anti-inflammatory drugs [NSAIDs]), nutritional (preoperative carbohydrate and immediate postoperative feeding), physical (maintaining normothermia, euolemia, and physical exercise), and hormonal (glycemic control). Guidelines for optimal perioperative care in colon, rectal, gastric, and pancreatic surgery¹⁰⁻¹³ include up to 25 evidence-based recommendations from all phases of perioperative care, involving multiple stakeholders (surgery, anesthesia, nursing, and patients). It is clear that as surgeons, if we only focus on the operation without being concerned with all of the other interventions our patients receive along the perioperative trajectory, our patients will not derive the maximal potential benefit of the minimally invasive approach. Even if the perfect laparoscopic bowel resection is performed, the impact will be much less if the patient comes out of the operating room hypothermic, fluid overloaded, and in pain. That patient is subsequently unlikely to be ready to eat or ambulate quickly, leading to more deconditioning and delaying full functional recovery.

In 1995 a Danish group led by Henrik Kehlet published a report on nine patients undergoing laparoscopic colonic resection who were treated with a multimodal intervention program including epidural analgesia, early oral nutrition, and mobilization.¹⁴ This was the first step for the development of fast-track programs, which later evolved into what are currently known as enhanced recovery pathways (ERPs). ERPs are evidence-based, multimodal, standardized care plans that integrate the multiple steps and interventions in the perioperative period. They aim to reduce the metabolic

response to surgery in multiple ways,⁹ but also to better organize care for patients undergoing a particular procedure, and thereby contribute to reducing unwanted variability in care processes and outcomes. A meta-analysis of 38 trials across multiple specialties concluded that ERPs reduced the risk of complications by about 30% and were associated with reduced hospital stays by about 1 day overall.¹⁵ The impact was consistent across specialties, which included colorectal, upper gastrointestinal, genitourinary, thoracic, and joint surgery. The approach also decreases costs, especially for the entire trajectory of perioperative care including posthospital costs.^{16–17} Including MIS as the foundation of an ERP and considering the entire care trajectory, from the preoperative phase through to full patient functional recovery, maximizes the value of the laparoscopic approach and its higher operating room equipment costs.

In this chapter, we first describe elements included in ERPs. We then review the evidence regarding the relative benefit of MIS and enhanced recovery on postoperative recovery. Finally, we provide an example of an ERP for bowel surgery to help others adopt this approach.

COMPONENTS OF ENHANCED RECOVERY PROGRAMS

ERPs represent a paradigm shift, from traditional care where the patient moves from one clinician-based expertise silo to the next, to a patient-centered pathway, where the steps of perioperative care are integrated. Interdisciplinary collaboration involving credible champions from surgery, anesthesiology, and nursing who will promote implementation with their constituencies is required. Creation of a new ERP begins by the team mapping out the trajectory of perioperative care at their institution and reviewing existing guidelines for each element of perioperative care, such as those from the Enhanced Recovery After Surgery (ERAS) Society.^{10–13} There are some elements that are common across a variety of procedures and some that are procedure specific, but the approach can be applied to any procedure (**Table 2.1**). The number of elements in a program per se does not seem to be critical, and success measured by a shorter hospital stay and complications has been seen with both complex and simpler programs.^{15,18} While the specific ways in which these elements are approached may vary from center to center, what seems most important is to come together as a team to create a multidisciplinary consensus for each element and from each phase of perioperative care about “how we’re going to do it at our hospital” for the average patient.

Daily care maps help with adherence as they provide consistency between the information received by patients and the health-care team. Beginning in the surgeon’s clinic and continuing with the preoperative clinic education, the patient and the patient’s family are provided with the daily plan for each day of hospitalization. This includes specific daily goals for nutrition, mobilization, drain management,

Table 2.1 Key elements to include in ERPs for gastrointestinal surgery

Preoperative	Optimization of organ dysfunction Patient education and engagement Prehabilitation/exercise Smoking abstinence Nutrition assessment/supplement Selective bowel preparation Limit preoperative fasting Carbohydrate drink No long-acting sedative
Intraoperative	Postoperative nausea and vomiting (PONV) prophylaxis Fluid therapy to achieve fluid balance Nerve block (when evidence based) Minimally invasive surgery Short-acting opioids Normothermia
Postoperative	Multimodal opioid-sparing analgesia (evidence based, procedure specific) Anti-ileus prophylaxis PONV prophylaxis Question use of drains, catheters, and monitoring (evidence based) Immediate or early oral nutrition Immediate ambulation Daily care maps, well-defined discharge criteria Postdischarge rehabilitation plan (evidence based)

Source: Kehlet H. *Langenbecks Arch Surg* 2011;396(5):585–90.⁶²

Note: This approach is applicable across procedures, but how each element is operationalized may differ depending on the available evidence for that procedure as well as available local expertise.

and pain control, as well as milestones to reach to enable discharge (**Figure 2.1**). When all of the recovery milestones are met, patients generally feel very comfortable leaving the hospital, even if this is earlier than with traditional care. Patients are encouraged to bring the information with them to the hospital, and the care maps are also posted on the ward. Patients are encouraged to speak up and ask questions about their own recovery trajectory and play an active role.

As with any quality improvement initiative, having data about both processes and outcomes is critical. Data collection should ideally begin when the ERP team is assembled, to show the team where they are starting. Length of stay (LOS) is an easy way to monitor outcomes within an institution as it relates to recovery, organization, complications, and cost. Readmissions and emergency department visits should also be monitored. However, it is also important to collect information about adherence to the different care processes that will be included in the ERP in order to understand those outcomes and how to improve care.

When creating a pathway for bowel surgery, key elements to address include preoperative patient education/

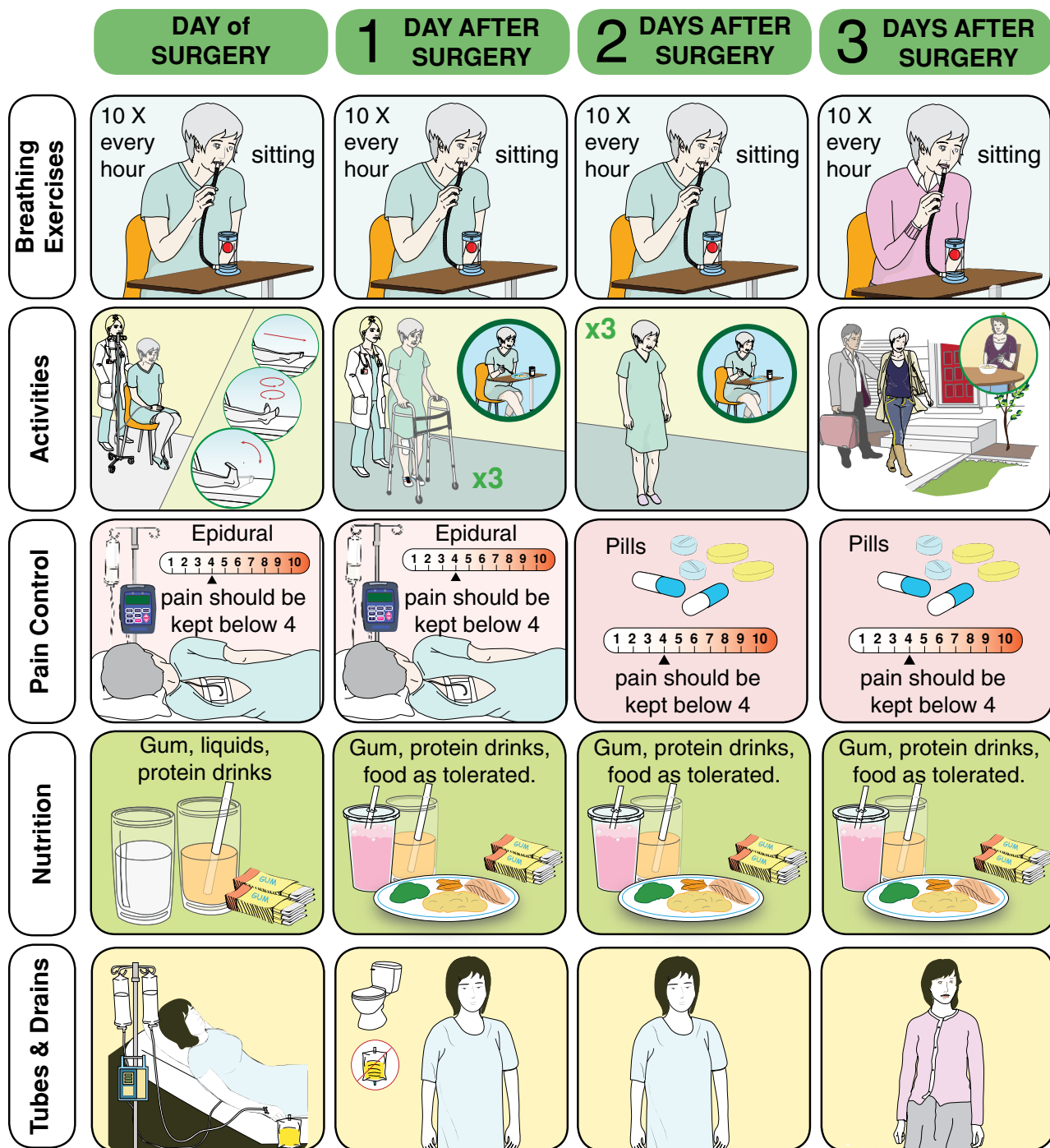


Figure 2.1 Example of daily care plan provided to the patient in an ERP for bowel surgery. (Used with permission of the MUHC patient information office.)

(Continued)

engagement, nutrition, fluid balance, opioid-sparing analgesia, exercise/mobilization, and use of drains. However, most of the evidence in the guidelines was from studies of open surgery. The significant role of MIS in reducing pain, ileus, and the inflammatory response means that some of the ERP objectives will be achieved differently for open and laparoscopic surgery. For example, thoracic epidural

analgesia is strongly recommended for open surgery¹¹ but may delay recovery after laparoscopic surgery,¹⁹ and simpler approaches, such as transversus abdominis plane (TAP) blocks, have been used successfully.²⁰ Similarly, for higher-risk patients undergoing major surgery, goal-directed fluid therapy using cardiac output monitoring is recommended, but in the context of laparoscopic surgery within an ERP,

Path to Home Guide: Bowel Surgery

	Day of surgery	1 Day after Surgery	2 Days after Surgery	3 Days after Surgery
Breathing Exercises	Do breathing exercises	Do breathing exercises	Do breathing exercises	Do breathing exercises
Activities	- Do leg exercises - Sit in a chair with help	- Sit in a chair for meals - Walk in the hallway 3 times, with help - Be out of bed for a total of 6 hours	- Sit in a chair for meals - Walk in the hallway 3 times - Be out of bed for a total of 6 hours	- Sit in a chair for meals - Be out of bed for a total of 6 hours - Go home today
Pain Control	- May have an epidural infusion for pain - Tell my nurse if pain reaches 4/10 on the pain scale	- May have an epidural infusion for pain - Tell my nurse if pain reaches 4/10 on the pain scale	- Start taking pills for pain - Have epidural catheter removed if my pain is controlled - Tell my nurse if pain reaches 4/10 on the pain scale	Tell my nurse if pain reaches 4/10 on the pain scale
Nutrition	- Drink liquids and protein drinks as tolerated - Chew gum for 30 minutes	- Drink liquids, including protein drinks - Eat regular food as tolerated - Chew gum for 30 minutes, 3 times/day	- Drink liquids, including protein drinks - Eat regular food as tolerated - Chew gum for 30 minutes, 3 times/day	- Drink liquids, including protein drinks - Eat regular food as tolerated - Chew gum for 30 minutes, 3 times/day
Tubes & Lines	I may have: - Oxygen mask or prongs (removed today) - Intravenous line - Epidural catheter - Urinary catheter	- My urinary catheter may be removed today - My intravenous line will be removed when I am drinking well	- My urinary catheter will be removed today, if it wasn't removed yesterday - My intravenous line will be removed when I am drinking well - My epidural catheter will be removed and my pain will be managed with pills	None

Figure 2.1 (Continued) Example of daily care plan provided to the patient in an ERP for bowel surgery. (Used with permission of the MUHC patient information office.)

similar results may be obtained using a simpler restrictive fluid approach.²¹

COMBINING LAPAROSCOPIC SURGERY WITH AN ERP

Both laparoscopic surgery and ERPs result in improved outcomes when used in isolation. Some elements of the ERP approach are already used more readily after laparoscopic surgery, such as early feeding. Are there advantages, beyond the theoretical, in adding a multidisciplinary ERP to a laparoscopic operation? In the following sections evidence regarding the relative benefit of MIS and enhanced recovery on postoperative recovery in different general surgery subspecialties is reviewed. This is in the form of a narrative review synthesizing studies found through literature searches performed in early 2015 using various combinations of “laparoscopic” or “minimally invasive” with “Enhanced recovery” or “Fast track” surgery.

Colorectal surgery

Two types of study designs have been used to evaluate the relative impact of MIS and ERP on recovery in the setting of colorectal surgery: (1) studies comparing open and laparoscopic surgery for patients treated within an ERP

and (2) studies comparing conventional perioperative care to enhanced recovery in patients undergoing laparoscopic resection. Five randomized clinical trials (RCTs)^{22–26} compared laparoscopic versus open surgery when an ERP is in use (Table 2.2). Two early studies were single-center trials with a relatively small sample of patients and yielded contrasting results. Kehlet’s group found no difference in length of hospital stay, postoperative complications, gastrointestinal function, or patient-reported outcomes after open or laparoscopic colectomy when treated with enhanced recovery,²² suggesting that when an ERP is used, the benefits ascribed to laparoscopy could be achieved with open surgery. In contrast, Kennedy’s group reported improved LOS, lower pain scores, and greater physical performance 2 weeks after laparoscopic compared to open surgery.²³

Two large multicenter RCTs were subsequently published: the LAFA study in the Netherlands,²⁴ and the EnRol trial in the United Kingdom.²⁶ The LAFA study allocated 400 patients undergoing colonic segmental resection for cancer to one of four groups combining surgical approach (laparoscopic or open) and perioperative care (enhanced recovery or standard). The combination of laparoscopy and enhanced recovery resulted in shorter length of hospital stay compared to the other groups, with laparoscopy the only independent predictor of reduced length of hospital stay. No differences were found for secondary outcomes including morbidity and quality of life. In a subset of patients, gastrointestinal recovery as measured by scintigraphy was faster in patients

Table 2.2 Characteristics and outcomes of randomized controlled trials evaluating laparoscopic versus open colorectal surgery within an enhanced recovery pathway

Study	Sample size		Type of surgery	Primary outcome	Postoperative morbidity			Total hospital stay			Readmissions		
	Lap	Open			Lap	Open	P-value	Lap	Open	P-value	Lap	Open	P-value
Basse et al. ²²	30	30	Colon	Length of stay	8 (27%)	6 (20%)	>0.05	Mean 3.8	Mean 3.9	>0.05	6 (20%)	8 (27%)	>0.05
King et al. ²³	41	19	Colorectal	Length of stay	6 (15%)	5 (26%)	0.21	Mean 5.5 (4–7)	Mean (95%CI) 8.3 (6–11)	0.012	2 (5%)	5 (26%)	0.027
LAFA ²⁴	100	93	Colon	Length of stay	34 (34%)	43 (46%)	>0.05	Median (IQR) 5 (4–7)	Median (IQR) 6 (4.5–10)	0.005	6 (6%)	7 (8%)	>0.05
Wang et al. ²⁵	40	41	Colon	Immune function	3 (8%)	7 (17%)	>0.05	Mean (SD) 5.2 (3.9)	Mean (SD) 6.5 (4.1)	<0.05	1 (3%)	3 (7%)	>0.05
EnRo ²⁶	103	101	Colorectal	Fatigue	32 (31%)	36 (36%)	0.55	Median (IQR) 5 (4–6)	Median (IQR) 6 (4–9)	0.011	14 (14%)	10 (10%)	0.38

Note: CI, confidence interval; IQR, interquartile range; Lap, laparoscopy; SD, standard deviation.

treated with laparoscopic surgery and enhanced recovery compared to the other groups. Both laparoscopy and enhanced recovery were independent predictors of faster colonic transit, earlier time to tolerance of solid food, and defecation.²⁷ Immune status and stress response after surgery were evaluated in another subset of patients from the LAFA trial.²⁸ Laparoscopy and not the type of perioperative care was an independent factor of better-preserved immune competence and reduced inflammation. In a randomized study with a design similar to the LAFA trial, Wang et al.²⁵ confirmed that the inflammatory response was attenuated in patients treated with MIS compared to open surgery, while enhanced recovery similarly protected immune function in both laparoscopic and open surgery patients.

Finally, in the EnRol trial,²⁶ 204 patients planned for colorectal resection were randomized to open or laparoscopic surgery in 12 UK centers applying an extensive ERP with 30 care elements and blinding of patients and assessors. LOS was shorter with laparoscopy, but no other differences were seen for physical fatigue, body image, and quality of life 1 month after surgery. The authors concluded that laparoscopic surgery within an ERP is recommended because of the shorter hospital stay. Zhuang et al.²⁹ recently published a meta-analysis including the aforementioned studies. Pooled data revealed that total hospital stay including postdischarge readmissions was significantly shorter in patients who underwent a laparoscopic procedure. The total number of complications was also reduced for laparoscopy, while no difference was found between open and laparoscopic surgery for the number of patients developing at least one complication.

Several randomized trials^{30–35} and a larger number of case control studies^{36–43} have estimated the effect of enhanced recovery compared to conventional care when minimally invasive colorectal resection is performed. All but one study³⁰ reported that the implementation of an ERP in the context of MIS reduces LOS and accelerates recovery of gastrointestinal function. These findings are confirmed by larger case control studies from high volume institutions and a few available case match studies. A report from the Mayo Clinic³⁷ showed that 45% of patients treated within an ERP were discharged within 2 days after minimally invasive colorectal cancer surgery. Postoperative complications were similar between ERP patients and conventional care in most of the RCTs and nonrandomized studies. Focusing on economic analysis, in a prospective comparative trial where most patients had laparoscopic resections,¹⁶ the addition of an ERP resulted in lower societal costs compared to a conventional care strategy. After discharge, patients managed in the ERP institution incurred less productivity loss, had less caregiver burden, and made fewer visits to outpatient health centers. A recent Cochrane review of three RCTs and six case-controlled studies found that for patients having laparoscopic colectomy, the addition of an ERP reduced LOS without affecting morbidity.⁴⁴ In a large multicenter registry, increasing adherence with pathway elements and the use of laparoscopic surgery were both

independently associated with shorter hospitalization and complications.⁴⁵

Although the quality of the evidence is not uniformly high, the data suggest that for colorectal resection, combining minimally invasive surgery with an ERP offers the greatest benefit, both for patients and for the health-care system. To date, most of the studies have only focused on short-term in-hospital recovery outcomes such as LOS and morbidity,⁴⁶ and future studies should also include postdischarge functional recovery measures to better capture all dimensions of recovery both in the short and longer term.⁴⁷

Bariatric and foregut surgery

There are very few reports investigating the effectiveness of a formal multidisciplinary ERP in bariatric surgery. However, there are numerous reports about ambulatory bariatric surgery. McCarty et al.⁴⁸ reported 23-hour discharge in 84% of 2,000 consecutive patients undergoing laparoscopic Roux-en-Y gastric bypass (RYGB), with few complications and readmissions. In this very high volume group with low leak rates, this was accomplished by simple optimization of perioperative analgesia and early return to oral feeding; the most significant factor in predicting successful 23-hour patient discharge was surgeon experience. Similar results were reported in a systematic review including six series of RYGB patients and eight series of laparoscopic gastric banding patients with planned outpatient surgery.⁴⁹ However, a recent population-based study including more than 50,000 laparoscopic RYGB patients from the Bariatric Surgery Centers of Excellence database has raised concerns about increased risk of 30-day mortality and a trend toward increased risk of 30-day serious complications in patients with a LOS of 1 day or less.⁵⁰ Only a few studies have reported on the use of multidisciplinary ERPs for bariatric surgery. These suggest that for laparoscopic RYGB and sleeve gastrectomy, ERPs facilitate early discharge without increasing complication and readmission rates.^{51,52}

The use of enhanced recovery strategies in the context of minimally invasive gastric surgery is limited to a few studies. Grantcharov and Kehlet⁵³ found that an ERP was feasible and safe resulting in short hospital stays (median LOS was 4 days) in a consecutive series of patients undergoing laparoscopic gastric resection for cancer. Two small RCTs comparing ERP to conventional care in laparoscopic distal gastrectomy patients have been published.^{54,55} Although underpowered to detect differences in postoperative morbidity, both studies showed reduced hospital stays in the ERP group compared to conventional care, and one also found that enhanced recovery was associated with improved quality of life at 2 weeks after surgery.⁵⁴

Hepato-Pancreato-Biliary (HPB) Surgery

Few studies have focused on the role of enhanced recovery in laparoscopic liver surgery. In a case-control series, patients

Table 2.3 Example of a multimodal ERP for elective colorectal surgery**Preoperative Assessment and Optimization**

- Evaluation of medication compliance and control of risk factors: hypertension, diabetes, chronic obstructive pulmonary disease (COPD), smoking, alcohol, asthma, coronary artery disease (CAD), malnutrition, anemia
- Psychological preparation for surgery and postoperative recovery: provide written information and e-module link including daily milestones in perioperative pathway (diet and ambulation plan, management of drains) and expectation about duration of hospital stay (3 days for colon, 4 days for rectal)
- Physical preparation with exercises at home: aerobic 30 minutes/day, three times per week at moderate intensity; resistance exercises; breathing exercises
- Full oral mechanical bowel preparation with oral antibiotics for rectal resections; no prep for laparoscopic colectomy; stoma teaching as needed
- Nutritional preparation: oral nutritional supplements for patients with diminished oral intake or mild malnutrition

Day of surgery

- Drink clear fluids with carbohydrates up to 2 hours prior to operation unless risk factors are present (e.g., gastroparesis, obstruction, dysphagia, previous difficult intubation, pregnancy)

Intraoperative Management*Anesthetic management*

- Epidural catheter for open cases inserted at appropriate intervertebral level. Use local anesthetics and test epidural blockade for bilateral spread. Infusion of local anesthetics during surgery. Minimal amount of IV opioids throughout surgery. Intrathecal morphine as alternative for laparoscopic surgery
- Bilateral transversus abdominis plane (TAP) block with ketorolac IV for laparoscopic surgery
- Prophylactic antiemetics: one or more antiemetics based on baseline risk score
- Antibiotics and deep vein thrombosis (DVT) prophylaxis
- Avoid overhydration. IV Ringer lactate at 3 mL/kg/h for laparoscopic surgery; 5 mL/kg/h for open cases. Colloid 1:1 (Voluven) to replace blood loss
- Anesthesia protocol: total IV anesthesia (tiva)/desflurane/sevoflurane. Lidocaine 1.5 mg/kg bolus then 2 mg/kg/h for duration of case (in patients without epidural)
- Maintenance of normothermia (core temperature $>36^{\circ}$)
- Neuromuscular blockade to facilitate laparoscopic exposure at lower pressure pneumoperitoneum (12 mmHg)
- Maintain glucose below 10 mmol/L (180 mg/dL)
- Titrate anesthesia according to bispectral index

Surgical care

- Minimize incision size, minimally invasive approach if possible
- Accurate hemostasis and removal of debris
- Check integrity of anastomosis
- No routine nasogastric and abdominal drains
- Remove urinary catheter for right hemicolectomy

Postoperative Strategy*Postanesthesia care unit*

- Discharge criteria to ward: patient alert, cooperative, pain-free, warm, normotensive, able to lift legs, adequate urine output

Day of surgery (postoperative day 0)

- Out of bed when transferred to ward
- Drinking fluids including nutritional supplements. Hold oral intake if abdomen distended or nausea/vomiting
- Confirm working epidural with visual analog scale (VAS) for pain at rest, cough, and mobilization. Check skin site (repeated in subsequent days)
- Oral acetaminophen 650 mg every 4 hours and Celecoxib 200 mg PO BID $\times$ 72 hours then reassess
- Normal saline to keep vein open (30 mL/h) if has patient controlled analgesia (PCA)
- Gum chewing for 30 minutes TID (continue daily)

Postoperative day 1

- HepLock IV in morning of POD 1
- Urinary catheter removed in the morning
- Mobilized 4–6 hours
- Full oral diet including nutritional supplements
- Hold oral intake if abdomen distended. Nasogastric tube for persistent nausea and vomiting (repeated in subsequent days)

(Continued)

Table 2.3 (Continued) Example of a multimodal ERP for elective colorectal surgery*Postoperative day 2 and later (>48 hours)*

- Full mobilization
- Full oral diet including nutritional supplements
- Transition from epidural to oral medication (OxyContin + oxycodone + acetaminophen + NSAIDs) if epidural stop test successful (repeated in subsequent days if epidural stop test not successful)
- Discharge criteria: passing gas or stool, no fever, minimal pain (<4/10), walking unattended, eating

Postdischarge care

- Instructions while recovering at home and/or on chemotherapy/radiotherapy: eating normal diet (±supplements), exercise every day, avoid opioids for pain relief, psychological support
- Clinic visit postop day 14 to check wound and overall recovery. Discuss pathology and further treatment. Plan further follow-up

Source: Feldman LS et al. *ACS Surgery* 2013.⁶³

treated with an ERP were considered functionally recovered and achieved discharge criteria earlier compared to conventional care.^{56,57} A Dutch RCT (Orange II)⁵⁸ evaluating functional recovery following laparoscopic versus open left lateral liver resection within an ERP has recently been completed, but the results have not yet been reported.

In pancreatic surgery, where MIS is frequently adopted for both benign and malignant lesions of the distal pancreas, a few studies have also incorporated ERPs. A case-matched series including 100 patients undergoing laparoscopic distal pancreatectomy found that laparoscopy was associated with faster recovery of gastrointestinal function and significantly shorter LOS for uncomplicated patients compared to open surgery.⁵⁹ A smaller case-control series of 44 patients undergoing laparoscopic distal pancreatectomy reported that the implementation of an ERP was associated with faster return to normal gut function, reduced LOS, and cost saving compared to conventional care.⁶⁰

SAMPLE ERP FOR LAPAROSCOPIC BOWEL SURGERY

Excellent guidelines and reviews^{10–13,61} are available to aid clinicians in developing their own programs, and many adjust the recommendations for laparoscopic or open surgery. These guidelines make it clear that many elements are under the purview of anesthesiology and nursing whose participation is critical in ERP implementation. An example of an ERP for bowel surgery is provided in [Table 2.3](#).

CONCLUSIONS

Some surgeons may feel they are already providing enhanced recovery care to their patients after laparoscopic surgery by feeding patients early, encouraging early mobilization, and minimizing the use of drains. However, implementation of an ERP requires anesthesiologists, nurses, and patients to integrate care, introduce new approaches, and stop doing some things that are detrimental. While it is true that some interventions in an ERP are not traditionally in the purview of the surgeon,

bringing a team together around a patient certainly is and hopefully always will be.

Adopting a culture of enhanced recovery has benefited our institution in many ways. Adding an ERP helps maximize the value of laparoscopic procedures by decreasing costs and improving outcomes. Decreasing the LOS increases capacity. Creating ERPs requires a multidisciplinary team and facilitates discussions around quality. Fasting guidelines that were implemented in association with ERPs are now standard procedures, as is the bladder-scan protocol for urinary retention. Increased attention on the patient's role in recovery encourages a culture where people can speak up and be engaged in their own care.

Many surgical specialty organizations now promote adoption of ERPs, including the American College of Surgeons, by including ERP process measures as optional data collection in the colorectal-specific National Surgical Quality Improvement Program. The Society of American Gastrointestinal and Endoscopic Surgeons established an enhanced recovery task force to create the SMART (Surgical Multimodal Accelerated Recovery Trajectory) program. Through courses, workshops, the webpage, and a manual written in collaboration with the ERAS Society, SMART will promote the adoption of patient-centered enhanced recovery care principles that enhance the intrinsic benefits of minimally invasive surgery to further improve safety, efficiency, and outcomes.

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Flexible endoscopy



Warren and Lucia Prosperi, *Ether Day, 1846*, 1999–2001. Oil on canvas, 72 × 96 inches. Massachusetts General Hospital, Boston.
(Image courtesy Massachusetts General Hospital, Archives and Special Collections.)

The first surgical operation utilizing ether anesthesia took place at Massachusetts General Hospital (MGH), Boston, on October 16, 1846, in a surgical theater now known as the “Ether Dome.” This painting, made by husband-and-wife team Warren and Lucia Prosperi between 1999 and 2001, is based on a reenactment of this historic event in the Ether Dome. The Prosperis researched for more than a year into

the lives of the men involved, including dentist Dr. William Thomas Green Morton, who holds the flask of ether; surgeon Dr. John Collins Warren, who makes the incision; and patient Edward Gilbert Abbott, who was afflicted by a vascular tumor in his neck. The painting shows the fateful moment when the first painless incision was made into Abbott’s throat by Dr. Warren.

In this work, the Prosperis employed a technique called optical naturalism to depict the event with photographic realism. The perspective of this painting places the viewer to the side of the action, as if a member of the audience, where we have an overview of the patient, surgeons, and observers. Thus, we are granted an experience similar to those attending operations in the same space today. The Prosperis restaged the event utilizing models from Harvard Medical School and MGH for the historical figures, including

Drs. Warren M. Zapol and J. Philip Kistler for Morton and Warren, respectively. With the help of the Emerson College Theatre Department, which did the costuming and makeup, and original props from the hospital museum, the Prosperis photographed the scene in the Ether Dome in order to create studies for the final painting. The work was then painted on site in the theater—now a lecture hall—where the painting still hangs to this day.

Training and privileging surgeons and gastroenterologists in endoscopy

JUDY WANG AND BRIAN J. DUNKIN

INTRODUCTION

The natural advancement of surgery is to become less invasive and more accurate. Amazing developments have occurred over the last three decades to move from open surgery to minimally invasive to endoluminal across multiple surgical disciplines. In gastrointestinal (GI) surgery, this has resulted in a resurgence of surgeons performing procedures using a flexible endoscopic platform, either as an adjunct to surgery, or to replace it.

Unfortunately, the history of the role surgeons have played in developing therapeutic endoscopy has been forgotten, and surgical training in endoscopy has not traditionally been strong. As a result, some have called into question the qualifications of surgeons performing flexible GI endoscopy.

This chapter provides a brief history of the role surgeons have played in developing GI endoscopy, a review of surgical and medical training pathways in the field, and guidance on the granting of privileges to perform the procedures.

HISTORICAL ROLE OF SURGEONS IN FLEXIBLE GASTROINTESTINAL ENDOSCOPY

Surgeons have played an integral role in the creation of endoscopic techniques dating back to the nineteenth century. In 1853, the French urologist A. J. Desormeaux created a device that could be used to evaluate the interior of the urethra and bladder, and the term “endoscope” was coined.¹ In 1868 the German surgeon Adolph Kussmaul fashioned a metal pipe used to examine the esophagus and stomach. Unfortunately, the light illumination was not sufficient. However, in 1879, the German urologist Maximilian

Nitze and the Austrian electrical engineer Joseph Leiter made a cystoscope using an electric light source and, with continued advancements, were able to construct a modern esophagoscope and gastroscope.² In 1881, Johann Mikulicz-Radecki, a Polish-Austrian surgeon working for Theodore Billroth, created, with the help of Leiter, a rigid gastroscope with a curved distal tip and attached mirrors to create a 30° angle field of view. Using this device, Mikulicz was the first to describe the endoscopic view of a gastric carcinoma and perform the endoscopic removal of a bone obstructing the esophagus by pushing it into the stomach.³ By 1911 Henry Elsner had developed a semiflexible gastroscope that Rudolph Schindler, an army surgeon, used to pioneer the field of gastroscopy and publish an atlas of his findings in 1923.⁴

In 1930, Heinrich Lamm, a gynecologist, demonstrated that an image could be transmitted across a coherent fiber-optic bundle, thus ushering in the era of fiber-optic endoscopy. By 1968 the first endoscopic retrograde cholangiopancreatography (ERCP) was reported by William McCune, a surgeon at George Washington University Hospital in Washington, DC.⁵ A year later, Wolff and Shinya, a Japanese-born, U.S.-trained surgeon, performed the first snare colonic polypectomy.⁶ By 1980, Jeff Ponsky, a general surgeon, and Michael Guaderer, a pediatric surgeon, had developed the percutaneous endoscopic gastrostomy (PEG) tube.⁷ In 1988, Greg Stiegmann, a surgeon in Denver, Colorado, described variceal band ligation.⁸ In 2007, David Utley, an ear, nose, and throat surgeon, and George Triadafilopoulos, a gastroenterologist, teamed up to invent Stretta—the first endoluminal treatment for gastroesophageal reflux disease to be approved by the U.S. Food and Drug Administration. Utley would later go on to pioneer radiofrequency ablation of the esophageal mucosa for the treatment of Barrett esophagus—a technique

that has essentially replaced esophagectomy for the management of dysplastic Barrett esophagus.⁹ By 2010, Haru Inoue, a Japanese surgeon, published the first experience in performing natural orifice surgery for achalasia—the peroral endoscopic myotomy (POEM).¹⁰ Today, POEM is rapidly replacing Heller myotomy as the preferred treatment for achalasia.

Surgeons have played a role in pioneering every significant advancement in therapeutic endoscopy. Not only have they earned the right to perform these procedures, but they need them to advance the field of minimally invasive surgery (MIS).

TRAINING IN GI ENDOSCOPY

Both surgeons and gastroenterologists use flexible endoscopy to provide optimal patient care for GI diseases. This training is most often gained during a general surgery residency, colon and rectal surgery residency, or gastroenterology fellowship. Training can also be acquired once a practitioner is in practice. Regardless of the training pathway, the principles for training are the same:

1. Know the indications, limitations, and contraindications of endoscopic procedures
2. Perform procedures safely, completely, and expeditiously
3. Be able to administer moderate sedation
4. Properly interpret endoscopic findings
5. Identify risk factors and know how to manage complications
6. Understand medical, radiological, and surgical alternative approaches
7. Prepare endoscopy reports and communication with other members of the care team
8. Understand quality measurements and participate in continuous quality improvement

MEDICAL TRAINING IN FLEXIBLE ENDOSCOPY

Training for U.S. internists in GI endoscopy is governed by the American Board of Internal Medicine (ABIM). Gastroenterology is considered a subspecialty of internal medicine, and to become certified in the subspecialty physicians must:

1. Be previously certified in internal medicine by the ABIM
2. Satisfactorily complete the requisite graduate medical education fellowship training
3. Demonstrate clinical competence, procedural skills, and moral and ethical behavior in the clinical setting
4. Hold a valid, unrestricted, and unchallenged license to practice medicine
5. Pass the Gastroenterology Certification Examination

The ABIM mandates that the duration of the fellowship be 36 months with a minimum of 18 months spent on clinical care, and it is expected that graduating fellows can perform diagnostic and therapeutic upper and lower endoscopy.¹¹

In addition, gastroenterology fellowship training must be accredited by the Accreditation Council for Graduate Medical Education (ACGME), the Royal College of Physicians and Surgeons of Canada, or the Professional Corporation of Physicians of Quebec. The ACGME states that gastroenterology fellows must demonstrate competence in prevention, evaluation, and management of 19 different disease categories and competence in the performance of 12 procedures ([Table 3.1](#)).¹² In assessing competence, the ACGME states that the program must assess the fellow in patient management and performance of procedures in both the inpatient and outpatient settings. This assessment must involve direct observation during patient encounters. It is up to each individual program to define criteria for competence for all required and elective procedures. The ACGME also states that the record of evaluation must include the fellow's logbook or an equivalent method to demonstrate that each fellow has achieved competence in the performance of required procedures, but it does not define what constitutes an "equivalent method."

To better define a curriculum that meets the ACGME requirements for knowledge and skill in gastroenterology, four leading U.S. medical societies, the American Association for the Study of Liver Diseases (AASLD), the American College of Gastroenterology (ACG), the American Gastroenterological Association (AGA) Institute, and the American Society for Gastrointestinal Endoscopy (ASGE), created and endorsed the Gastroenterology Core Curriculum.¹³ First created in 1996, the curriculum is in its third edition (2007), with a fourth under revision. It is aligned with ACGME requirements for eligibility, training institute requirements, duration, duty hour compliance, and covered disease categories. In addition, it provides details on the scope of knowledge required within each disease category and guidance into the acquisition and verification of technical skill.

The Core Curriculum describes 18 months of clinical training, 3–6 months of research, and an additional 12 months of "elective" time that can be spent focusing on the trainee's interests, including additional clinical training or research. It further defines two levels of training: Level 1 is considered the core clinical requirement and is completed in 18 months. Level 2 is considered "enhanced clinical training" in the areas of geriatric gastroenterology, nutrition, advanced endoscopy (endoscopic retrograde cholangiography and endoscopic ultrasound), motility, hepatobiliary and pancreatic diseases, and hepatology, and is "commonly" completed during an additional 12 months of training beyond the 36 months of fellowship, but could be completed within the 12 months of elective time. The two levels of endoscopic training are for two distinct types of gastroenterologists. Level 1 includes gastroenterologists performing routine GI endoscopic and nonendoscopic procedures as part of the practice of gastroenterology, and gastroenterologists specializing in nonendoscopic aspects of gastroenterology, including, but not limited to, the study of liver

Table 3.1 ACGME required domains of knowledge and skill in gastroenterology training

Diseases	Procedures
• Acid peptic disorders of the GI tract • Acute and chronic gallbladder and biliary tract diseases • Acute and chronic liver diseases • Acute and chronic pancreatic diseases • Diseases of the esophagus • Disorders of nutrient assimilation • Gastrointestinal and hepatic neoplastic disease • Gastrointestinal bleeding • Gastrointestinal diseases with an immune basis • Gastrointestinal emergencies in the acutely ill patient • Gastrointestinal infections including retroviral, mycotic, and parasitic diseases • Genetic/inherited disorders • Geriatric gastroenterology • Inflammatory bowel disease • Irritable bowel syndrome • Motor disorders of the GI tract • Patients under surgical care for GI disorders • Vascular disorders of the GI tract • Women's health issues in digestive disease	• Biopsy of the mucosa of the esophagus, stomach, small bowel, and colon • Capsule endoscopy • Colonoscopy with polypectomy • Moderate sedation • Esophageal dilation • Esophagogastroduodenoscopy • Nonvariceal hemostasis, both upper and lower including actively bleeding patients • Other diagnostic and therapeutic procedures utilizing enteral intubation • Paracentesis • Percutaneous endoscopic gastrostomy (PEG) • Retrieval of foreign bodies from the esophagus • Variceal hemostasis including actively bleeding patients

diseases, motility, nutrition, and basic science research. Level 2 includes gastroenterologists who, in addition to all or part of the above, perform some or all advanced (both diagnostic and therapeutic) GI endoscopy procedures, including ERCP (with sphincterotomy, lithotripsy, stent placement, etc.), endoscopic ultrasound, endoscopic mucosal resection, endoscopic gastroesophageal reflux therapy, and laparoscopy.

When it comes to assessing procedural competence in GI endoscopy, the Core Curriculum states that “Endoscopic competence is difficult to define and quantify. Evaluation remains largely subjective; however, the objective assessment of competence is more desirable.” It then goes on to recommend a minimum threshold number of procedures to be completed by a trainee before competency can be assessed (Table 3.2). It is further stated that these numbers represent a minimum, and that most trainees require more, but never less, to achieve competency. No references are provided as a basis for the numbers. Procedural Competence Assessment Forms are provided in an appendix of the document for diagnostic upper and lower endoscopy, but no validation science is provided supporting these tools, and no threshold of performance is suggested.

ASGE has also published core curricula for esophagogastroduodenoscopy (EGD) and colonoscopy.^{14,15} The EGD curriculum does not discuss assessment. The colonoscopy curriculum recommends using the Mayo Colonoscopy Skills Assessment Tool (MCSAT) throughout training with a goal of achieving a score of 3.5 or higher in all domains. This document also discusses use of quality metrics for practicing gastroenterologists,

including cecal intubation rates, polyp detection rates, and appropriate recommendations for patient follow-up. ASGE recognized limitations of the MCSAT including the fact that some of its questions were too broad to be answered accurately and that it could not be used

Table 3.2 ASGE guidelines for endoscopic training in routine procedures: Threshold for assessing competency

Procedure	Required number ^a
Esophagogastroduodenoscopy	130
Including treatment of nonvariceal hemorrhage (10 actively bleeding)	20
Including treatment of variceal hemorrhage (5 actively bleeding)	10
Esophageal dilation (guidewire and through the scope)	20
Colonoscopy	140
Including snare polypectomy and hemostasis	30
Percutaneous endoscopic gastrostomy placement ^b	15
Capsule endoscopy (small bowel)	25

Note: The information in this table represents the current recommendation of the ASGE. Because ASGE guidelines are living documents, they undergo frequent revision. Please check the ASGE website (www.asge.org) to obtain the most current information.

^a “Required number” represents the threshold number of procedures that must be performed before competency can be assessed. The number represents a minimum, and it is understood that most trainees will require more (never less) than the stated number to meet the competency standards based on existing data.

^b Refers to the gastric component of the PEG tube placement.

for EGD. As a result, it has developed the Assessment of Competency in Endoscopy (ACE) forms and recommends that these be used for assessment on at least 10% of gastroenterology fellow performed cases.¹⁶ Although ACE was created from modifying the MCSAT—an assessment tool backed by validation science—the ACE form itself has no validity evidence supporting it.

SURGICAL TRAINING IN FLEXIBLE ENDOSCOPY

General surgery

Training programs in general surgery in the United States are governed by the ACGME in a similar fashion to internal medicine and gastroenterology. Individual surgeons are certified in general surgery by the American Board of Surgery (ABS). Flexible GI endoscopy is one of 16 defined categories of procedures that general surgery residents are expected to become competent in during 5 years of clinical training (Table 3.3).¹⁷

Until 2014, a minimum case number of 35 EGDs and 50 colonoscopies served as the clinical basis to assess technical competency. Procedures done as part of surgery (e.g., EGD during Nissen fundoplication; colonoscopy to localize a tumor during colectomy) could not be included in these numbers. The ABS has recognized that flexible endoscopy is an important component of procedures that general surgeons provide for patients and represents a natural extension of MIS. In 2007, 74% of rural surgeons performed more than 50 flexible endoscopic procedures each year, with 42% of rural surgeons performing more than 200 flexible endoscopic procedures annually.¹⁸ In a 2010 report on rural, underserved areas that lack gastroenterology services, 39.8% of an American general surgeons' practice comprises flexible endoscopic procedures.¹⁹ In Canada, surgeons are the primary providers of flexible endoscopic services in smaller urban and rural areas.²⁰ As a result, the ABS partnered with four surgical societies, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES), the Society for Surgery of the Alimentary Tract (SSAT), the American Society of Colon and Rectal Surgeons (ASCRS), and the American Society of Metabolic and Bariatric Surgery (ASMBS), to create a formal curriculum in flexible endoscopy.²¹ The ABS Flexible Endoscopy Curriculum (FEC) is a 5-year distributed curriculum begun in the first year of general surgery residency. It provides a stepwise, milestone-based instructional program for residents to acquire the essential knowledge and skills to perform flexible endoscopy and assesses competence using validated assessment tools. Upon successful completion of the curriculum, a general surgery resident will possess the knowledge and skill to be a surgical endoscopist with the ability to provide endoscopic services to patients in any clinical setting. A *surgical endoscopist* is a surgeon who has the knowledge and

Table 3.3 Minimum case numbers for general surgery residents for the academic year 2017–2018

Category	Minimum
Skin, Soft tissue	25
Breast	40
Mastectomy	5
Axilla	5
Head and neck	25
Alimentary tract	180
Esophagus	5
Stomach	15
Small intestine	25
Large intestine	40
Appendix	40
Anorectal	20
Abdominal	250
Biliary	85
Hernia	85
Liver	5
Pancreas	5
Vascular	50
Access	10
Anastomosis, repair, or endarterectomy	10
Endocrine	15
Thyroid or parathyroid	10
Operative trauma	10
Nonoperative trauma	40
Resuscitations as team leader	10
Thoracic surgery	20
Thoracotomy	5
Pediatric surgery	20
Plastic surgery	10
Surgical critical care	40
Laparoscopic basic	100
Endoscopy	85
Upper endoscopy	35
Colonoscopy	50
Laparoscopic complex	75
Total major cases	850
Chief year major cases	200
Teaching assistant cases	25

Source: Defined Category Minimum Numbers: General Surgery Effective for Program Graduates Beginning Academic Year 2017–2018. ©2017 Accreditation Council for Graduate Medical Education (ACGME).

Note: Case logs for residents graduating in 2018 will be assessed using these new minimums beginning with the 2019 ACGME Annual Program Review.

technical skill to use flexible endoscopy to provide care for patients with common GI diseases. This ability includes the following:

1. An understanding of the indications and contraindications for performing upper and lower endoscopy
2. Accurate recognition and management of normal and abnormal findings in the GI tract

3. Recognition and management of complications from performing GI endoscopy
4. Safe performance of upper and lower endoscopy, including complete navigation of the esophagus, stomach, proximal duodenum, and colon
5. Mucosal inspection and recognition of lesions that may require surgery
6. Tissue acquisition using biopsy or polypectomy
7. Management of periprocedural bleeding
8. Placement of a percutaneous endoscopic gastrostomy

The ABS-FEC contains five levels. Each level defines cognitive and technical milestones to be achieved and recommended resources to use. Didactic material supporting the FEC includes the Surgical Council on Resident Education (SCORE) Portal—a program containing high-quality educational materials and a structured program for self-learning in all areas of general surgery—and the Fundamentals of Endoscopic Surgery (FES) web modules.^{22,23} Technical training comes from work on physical or computer simulators and clinical cases performed both inside and outside of the operating room. The ABS-FEC also uses a validated clinical assessment tool for measuring the performance of upper and lower endoscopy (the Global Assessment of Gastrointestinal Endoscopic Skills [GAGES]) and a high-stakes test of knowledge and skill through the FES program.

GAGES is a global assessment form used to evaluate performance in upper and lower endoscopy.²⁴ Each form (GAGES-UE; GAGES-C) assesses five domains on a Likert scale of 1–5 with strong anchors at 1, 3, and 5. A maximum score of 25 is possible. Multi-institutional testing has shown excellent performance by the GAGES tool to separate novice from expert performance. It is also easy to administer, consistent, and meets high standards for reliability and validity. Reliably achieving GAGES scores of 18 or higher for both upper and lower endoscopy is required for successful completion of the ABS-FEC.

The FES is a high-stakes test of knowledge and skill in flexible GI endoscopy. It consists of three components. The first is web-based didactic material covering the knowledge required to safely and effectively use endoscopy in practice. The second is a multiple choice exam administered in a secure testing environment at an approved testing center. The third is a test of technical skill using a computer-based simulator also administered at an approved testing center. Validation studies support the use of FES as a high-stakes exam, and passage of the exam is required before a general surgery resident can take the ABS qualifying exam—the first step toward board certification.^{25,26}

Now that the ABS-FEC has been implemented, beginning in July 2018, every graduating general surgery resident in the United States will have been required to successfully complete a 5-year distributed curriculum in flexible GI endoscopy that includes minimum case numbers, requisite didactic material review and skills rehearsal, validated

assessment of clinical performance, and a high-stakes exam. This will serve as the basis for taking the ABS qualifying exam. If successfully completed, the candidate will then take the ABS certifying exam; an oral exam with six expert examiners who are required to pose a minimum number of questions in the domain of flexible endoscopy.

Colon and rectal surgery

Colon and rectal surgery (CRS) is the specialty that focuses on the medical, surgical, endoscopic, and perioperative management of disorders involving the colon, rectum, and anus, and related problems of the abdomen, pelvis, and perineum. Training programs providing training in CRS are governed by the ACGME.²⁷ Entry into training requires successful completion of an ACGME or Royal College of Physicians and Surgeons of Canada (RCPSC)-accredited residency program in surgery of not less than 5 years of progressive education, and to be certified by the American Board of Surgery (ABS) or have completed the educational requirements to sit for the ABS qualifying examination. Training duration is 12 months beyond general surgery residency. Graduates must “demonstrate a high level of skill and dexterity in the performance of all essential colon and rectal surgical procedures.” Endoscopy, including anoscopy, diagnostic and therapeutic colonoscopy, and rigid and flexible sigmoidoscopy are considered essential. Minimum case numbers are suggested by the ACGME (140 colonoscopies, 30 with intervention beyond biopsy), but they are not required for board certification by the American Board of Colon and Rectal Surgeons.^{28,29}

Fellowship Council flexible endoscopy fellowship

The Fellowship Council (FC) is an organization created to foster the development of high-quality non-ACGME-approved fellowships in MIS, GI surgery, flexible endoscopy, bariatric and metabolic surgery, noncardiac thoracic surgery, advanced colon and rectal surgery, and hepato-pancreato-biliary (HPB) surgery through a program accreditation pathway and universal application and matching process.³⁰ A FC flexible endoscopic fellowship focuses on the treatment of patients and diseases that require advanced endoscopic techniques. The fellowship provides experience in advanced upper and lower endoscopic procedures and focuses on therapeutic endoscopy.

The FC defines a suggested curriculum for its flexible endoscopy fellowships.³¹ While case numbers for individual procedures are not required, a minimum of 100 therapeutic endoscopic procedures must be performed annually by the fellow to be accredited as a FC Flexible Endoscopy fellowship. Except for ERCP, no metrics of performance are suggested for the FC curriculum.

Table 3.4 summarizes the requirements for medical and surgical training in flexible GI endoscopy.

Table 3.4 Requirements for medical and surgical training in flexible GI endoscopy

	GI fellowship	General surgery residency	Colon and rectal surgery residency	Fellowship Council flexible endoscopy fellowship
Minimum case volume	✓ ^a	✓		✓
Written knowledge test ^b		✓		✓ ^c
Oral knowledge test		✓		✓
Validated assessment of clinical performance		✓		✓
Case log		✓	✓	✓
Duration of training (months)	18	60	12	12

^a No case log required.

^b Specific to performance of flexible endoscopy and separate from Board exams.

^c FES certification required.

TRAINING WHILE IN PRACTICE

Once a physician has completed formal residency and fellowship training, it can be difficult to learn how to perform flexible endoscopy while in practice. A significant barrier is the legal and regulatory requirements for a practicing clinician to participate in hands-on clinical cases. In an effort to overcome this obstacle, some professional societies have partnered with world-class international institutes to provide this hands-on experience.

The European Society of Gastrointestinal Endoscopy (ESGE) offers two levels of training for practicing physicians. Module I is entitled “Basic Training with Experts” and provides training on basic steps and specific techniques. A maximum of 4 weeks of training is foreseen, and hands-on clinical training is not provided. Module II, entitled “Advanced Training with Experts,” lasts from 3 to 6 months depending on the number of procedures involved and on the field of expertise of the host training center. Learners get hands-on training on specific techniques during this period. Fourteen international centers participate in Module II training.³²

The SAGES has been piloting a novel program for practicing surgeons. It combines online didactic material review with 3 days of stateside laboratory skills and case observation. Participants then travel to a world-class institute in Asia to participate in a high volume of clinical procedures. Surgeons participating in this program are required to be FES certified and will perform nearly 300 procedures over 2 weeks. Clinical performance is assessed using GAGES.

PRIVILEGING IN FLEXIBLE GI ENDOSCOPY

Credentialing represents the verification of a person’s education, training, and experience. Privileging gives permission for a person to engage in specific clinical activities. Current credentialing and privileging structure in the United States requires that each health-care facility manage the process. This leaves many facilities looking for guidance on how to grant privileges to clinicians who wish to perform flexible endoscopic procedures. Both medical and surgical professional societies have created guidelines to

help in these decisions. However, the guidelines often differ significantly in their recommendations. Two of the leading societies in this space are SAGES and ASGE.

In 2016, SAGES published updated guidelines for privileging and credentialing in GI endoscopy.³³ This guideline put forth a number of recommendations for granting privileges. The first is to apply a uniform standard to all physicians requesting privileges to perform endoscopy and that these standards use evidenced-based criteria. The goal is to grant privileges to all physicians with proper training and experience so as to ensure the delivery of high-quality and safe patient care.

Another recommendation is the requirement that all physicians privileged in endoscopy have completed a program that includes formal training in endoscopy. This program could be a general surgery residency, gastroenterology fellowship, colon and rectal surgery residency, or a mini-fellowship (for those who sought training outside of a formal residency program), as long as the fellowship fulfills the requirements for minimal case volumes, knowledge of GI diseases, objective assessment of performance, and certification of proficiency by a qualified endoscopist.

SAGES also states that, while efficiency in endoscopy increases with increasing experience, quality measures in endoscopy and complication rates are not related to specialty or case volumes. As a result, objective assessment of procedural competence using validated tools should be used rather than case numbers alone. The guidelines also state that completion of a comprehensive endoscopy curriculum, which includes use of validated assessment tools, may make one eligible for initial privileging for endoscopy, but that assessment of skills and outcomes after granting privileges should be intensive, individualized, and ongoing. They suggest using a Focused Professional Practice Evaluation (FPPE) to evaluate endoscopic skills, assess quality metrics, and follow patient outcomes. They also recommend periodic Ongoing Professional Practice Evaluations (OPPEs). FPPEs and OPPEs have long been used in surgery for ensuring competence in other surgical procedures.

Finally, SAGES recommends that renewal and maintenance of privileges should include assessment of quality metrics and participation in quality improvement measures.

Figure 3.1 outlines SAGES' suggested checklist for initial privileging in GI endoscopy.

In 2017, ASGE published their guidelines for privileging, credentialing, and proctoring to perform GI endoscopy.³⁴ The authors state that, whenever possible, competence should be determined based on objective criteria and direct observation. Performance of an arbitrary number of procedures does not guarantee competency because of differences in individual learning curves. ASGE then goes on, however, to state that minimum threshold numbers may be set, below which competency cannot be assessed, and they provide their opinion on what these numbers should be for 14 different procedures.

Multiple societies have criticized the ASGE document in writing. They highlight the inherent problem of utilizing procedural numbers as a surrogate for measuring technical skill, the importance of quality training, and point out a number of methodological issues with the ASGE guideline. To begin with, procedural numbers are an inadequate measure of competence. Individual learning curves of technical skills vary based on natural talent, dedicated and deliberate practice time, and educational exposure of learners to procedures.³⁵ Competency is better attained when training goals are set for learners and training is tailored to individual needs. Goal-oriented training ensures that competence is acquired uniformly

1. Evidence of adequate training

- _____ Completion of ACGME accredited residency program in general surgery, fellowship in colorectal surgery, pediatric surgery, or gastroenterology.
- OR
- _____ Completion of training program with experience equivalent to one of the above.
- OR
- _____ Completion of an intense immersion training program with a robust curriculum that achieves endoscopic competence equivalent to one of the above.

2. Evidence of technical skill

- _____ Acknowledgment and attestation of skill level by current or past department chief or supervising physicians
- AND
- _____ Successful performance scores on a validated assessment tool of endoscopic skill

3. Participation in an ongoing quality assessment program

- _____ Track the following metrics for colonoscopy
 - Quality assessment cecal intubation rate
 - Adenoma detection rate
 - Complications (perforation, bleeding, sedation complications).
 - Follow up recommendations
- AND
- _____ Perform FPPE and OPPE per institution guidelines for both upper and lower endoscopy
- AND
- _____ Participation in an ongoing quality assessment program
- AND
- _____ Periodic OPPE
- AND
- _____ FPPE for recognized deficiencies

Figure 3.1 SAGES suggested checklist for initial privileging in GI endoscopy.

by learners, independent of numbers of procedures required by each trainee.³⁶ The superiority of goal-oriented over number-based training has been shown by experts in the field.^{37,38}

There are also methodologic issues with the ASGE guideline. First, the results of their systematic review are not provided, making it hard to verify the accuracy of the work. Second, the overall quality of the available evidence and number of published studies is extremely limited to draw meaningful conclusions, let alone define robust procedural thresholds for competency and certification. Third, the ASGE guidelines apply inconsistent criteria when defining minimum threshold numbers. They use the highest reported number according to their systematic review for colonoscopy ($n = 275$, range 75–280), a higher number for ERCP ($n = 200$, range 70–185), and an intermediate number for EUS ($n = 225$, range 78 to >400). In addition, numbers recommended for more complex procedures, like endoscopic mucosal resection ($n = 20$) or endoscopic submucosal dissection ($n = 30$), are small compared to numbers listed for EGD ($n = 130$) and colonoscopy.

Based on this information, multiple societies have recommended that the numbers proposed in the ASGE document not be used for granting privileges for GI endoscopy.

CONCLUSIONS

Both surgeons and gastroenterologists play an important role in providing endoscopic services to patients. Both specialties have created credible training pathways that lead to competence in performing flexible endoscopy. Privileging for these procedures should recognize these pathways and be based on uniform standards that do not rely on procedure numbers alone, but include valid assessments of knowledge and skill. After the granting of initial privileges, maintenance and renewal of privileges should be based on assessments of quality and participation in quality improvement measures.

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Anesthetic challenges in the gastrointestinal suites

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INTRODUCTION

The number and types of cases performed in the gastrointestinal suites settings are exploding. With advances in therapeutic technology, common gastrointestinal conditions that in the past may have required an open surgery are now often amenable to noninvasive procedures.^{1,2} At the same time, the demand for noninvasive diagnostic studies using an endoscopic ultrasound and other modalities has led to a significant increase in the volume of cases. These complex procedures frequently require a deep level of sedation or anesthesia.^{3,4} To accommodate the increased demand, many suites are now frequently equipped to allow the delivery of deep sedation and even general anesthesia in addition to traditional nurse-administered moderate sedation.⁴

An understanding of the different sedation and anesthesia options available is important when choosing the type of sedation or anesthesia for these cases. Appropriate choices can improve patient and provider outcomes, including satisfaction.⁵ This chapter highlights the differences between anesthesia options, common medications administered, and potential hazards of sedation during some of the more common procedures encountered.

WHAT TYPES OF SEDATION AND ANESTHESIA ARE AVAILABLE?

The American Society of Anesthesiologists describes four levels of sedation—minimal, moderate, deep, and general anesthesia ([Table 4.1](#)).⁶ Most simple endoscopy cases are performed with either nurse-administered moderate sedation or using deep sedation with propofol with an anesthesia provider, referred to as Monitored Anesthesia Care (MAC). Less commonly, a patient may require a general anesthesia and endotracheal intubation, usually in cases that are painful, are prolonged, or carry a significant risk of aspiration, hypoventilation, or general hemodynamic instability. The type of sedation and anesthesia required for an endoscopy case depends on the patient, both expectations and comorbid conditions, and the invasiveness of the procedure.⁷ Certain patient conditions increase the difficulty of administering sedation; for example, a history of opioid tolerance, alcohol, and regular illicit drug use can increase the patient's tolerance to common sedatives such as benzodiazepines and opioids ([Table 4.2](#)). These patients will be challenging to sedate without very large doses of medications and

Table 4.1 American Society of Anesthesiologists level of sedation

	Minimal sedation	Moderate sedation	Deep sedation	General anesthesia
Responsiveness	Normal response to verbal stimulation	Purposeful response to verbal and tactile stimulation	Purposeful response following repeated or painful stimulation	Unarousable, even with painful stimulus
Airway	Unaffected	No intervention required	Intervention may be required	Intervention often required
Spontaneous ventilation	Unaffected	Adequate	May be inadequate	Frequently inadequate
Cardiovascular function	Unaffected	Usually maintained	Usually maintained	May be impaired

Source: American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists. *Anesthesiology* 2002;96(4):1004–17.

Table 4.2 Predictors of difficult sedation

Heavy alcohol or substance abuse
Chronic pain medications and tolerance
History of difficult sedation in the past
Obstructive sleep apnea
Obesity
Unstable or severe medical condition
Significant dementia or developmental cognitive conditions
Symptomatic psychiatric conditions

are likely to need deep sedation with MAC even for a simple procedure. A major challenge when administering sedation is keeping patients in the correct “zone,” and understanding the pharmacological profiles of the medications administered is important.⁷

MONITORING

All patients receiving moderate, deep, or general anesthesia must be monitored. Standard basic monitoring includes continuous electrocardiogram, pulse oximetry with audible tones, and noninvasive blood pressure monitoring at a minimum of 5-minute intervals. Continuous capnography (end tidal CO₂ monitoring) is required for MAC patients undergoing deep sedation or patients receiving general anesthesia. In 2011 the American Society of Anesthesiologists standard (www.asahq.org) also recommended capnography for patients undergoing moderate sedation, but this is not universally accepted. Capnography, or noninvasive, real-time measurement of carbon dioxide (CO₂) measures ventilation through detection of maximum partial pressure of CO₂ at the end of an exhaled breath, or end-tidal CO₂ (EtCO₂), to form a graphic waveform describing the distinct phases of the respiratory cycle. Using capnography, it is possible to detect alveolar hypoventilation prior to the development of hypoxemia, providing an early warning of impending hypoxemia and providing time for appropriate intervention.^{8,9}

MEDICATIONS

In the United States, an increasing percentage of colonoscopies is being performed with deep sedation with propofol under the direction of an anesthesiologist, and an estimated increase from approximately 20% to 50% of upper endoscopic and colonoscopy procedures in 2015 is expected.^{1,10} For cases done under moderate sedation, over 75% of providers use a combination of midazolam and fentanyl.¹⁰ A brief description of the common medications used is included in the next section ([Table 4.3](#)).

Benzodiazepines

Midazolam is a short-acting benzodiazepine, with a rapid onset. Midazolam is extremely lipophilic and is metabolized by the liver, and the dose should be reduced in elderly patients and in those with renal insufficiency. In obese patients, large doses may lead to extended action. Midazolam is a sedative that has anxiolytic and amnesic properties making it an excellent medication for procedural sedation. It has no analgesic properties and is generally combined with a short-acting opioid such as fentanyl. Although it has limited cardiovascular effects, hypotension can occur when combined with an opioid, especially in hypovolemic patients. In adults the usual dose is 2–6 mg intravenously in divided doses.

Opioids

Fentanyl is a short-acting synthetic opioid that is most commonly used in combination with midazolam for moderate sedation. It is lipophilic, rapidly crosses the blood-brain barrier, and has a rapid onset. Dosing should be done incrementally and titrated to effect, and reduced in the elderly and patients with sleep apnea, either diagnosed or suspected. Respiratory depression occurs through a central ventilatory suppression of brainstem neurons and also through a muscle relaxant effect that can lead to airway obstruction, particularly in frail, obese, or elderly patients. Other side effects common to opioids include nausea and vomiting,

Table 4.3 Suggested moderate sedation drug dosage information

	Initial IV dose (titrate)	Maximum cumulative	Cautions
Benzodiazepines			
Healthy adults <70 years	0.5–2 mg IV	6 mg	Hepatic insufficiency, reduce if concomitant opioids given
Elderly adults >70 years, or debilitated chronically ill patients	0.5–1.5 mg	4 mg	Fifty percent reduction other opioids; increased susceptibility to respiratory depression and apnea
Opioids			
Fentanyl	Initial dose 25–50 mcg IV, titrate 25 mcg at intervals	2 mcg/kg to total of 200 mcg	Hepatic insufficiency, decrease dose; reduce doses with concomitant benzodiazepines; reduce by 50% for elderly patients

itching, and muscle rigidity, although the latter is unlikely to occur with small doses used for sedation. The usual dose range for procedures is 25–150 mcg intravenously.

HYPNOTIC AGENTS

Propofol

Propofol is a hypnotic anesthetic agent. The central nervous system effects are dose dependent, ranging from light sedation at lower doses to deep sedation and ultimately hypnosis or unconsciousness (general anesthesia) at larger doses. Following injection, Propofol undergoes rapid distribution and subsequent redistribution from central to peripheral compartments and elimination; these properties make continuous infusion a popular option. In addition to the impact on consciousness, propofol has significant respiratory and cardiovascular effects. With a large bolus dose, apnea will frequently ensue for 30–40 seconds, and during infusion a decrease in tidal volume and increase in rate are commonly observed. There is a significant risk of apnea or hypoventilation with propofol as it also blunts the normal response to hypercapnia and hypoxia. Propofol can also cause myocardial depression as well as peripheral and arterial vasodilation leading to significant hypotension; this is most common after a bolus dose and exacerbated by hypovolemia. In older patients, the dose should be reduced, and the effect can be delayed due to age-related changes in the initial volume of distribution and intercompartmental clearance. Pain on injection is common with propofol, but this can be minimized by the addition of 20–40 mg lidocaine with the injection and by using bigger veins. Usual bolus doses range from 10 to 30 mg, and infusion rates range from 40 mcg/kg/h to over 150 mcg/kg/h depending on the type of procedure and the patient's age and comorbidities.

Unlike the opioids and benzodiazepines, there is no reversal agent for propofol, and because of the rapid transition that may occur from light sedation to unconsciousness general anesthesia with potential apnea, providers administering propofol should be prepared to provide respiratory support via bag mask ventilation or endotracheal intubation.

Ketamine

Ketamine is a *N*-methyl-D-aspartate (NMDA) receptor antagonist, and acts by suppressing thalamocortical systems and stimulating the limbic pathways, producing dissociative anesthesia. This is characterized by profound analgesia and amnesia, with little or no impact on respiration or protective reflexes. For procedural sedation, ketamine is most commonly given with propofol for its analgesic and respiratory-sparing properties. Small doses of midazolam are also commonly employed, and in these conditions the

hallucinatory side effects are uncommon. Ketamine has strong cardiovascular stimulating impacts and can produce significant hypertension and tachycardia. It can also lead to an increase in oral secretions that can be reduced by giving a small dose of an antisialagogue drug such as glycopyrrolate as a premedication. Usual ketamine doses for procedural sedation are 10–40 mg intravenous bolus in divided doses, used as an adjuvant with other agents.

REVERSAL AGENTS

Flumazenil is a competitive antagonist specific to benzodiazepines; during procedural sedation, it is most commonly used to partially reverse or reduce the respiratory effects of midazolam. The usual dose is between 0.5 and 3 mg intravenously. It is short acting and can be expected to provide antagonism of 45–90 minutes. Reversal with flumazenil is not associated with cardiovascular or stress effects.

Naloxone is a μ -opioid receptor competitive antagonist used to reverse the respiratory depression associated with fentanyl. It is a short duration drug lasting only 15–45 minutes, and when longer-acting opioids have been administered, a continuous infusion or re-dosing may be necessary. In general, naloxone should be titrated slowly starting with 40–80 mcg intravenous boluses. It reverses the respiratory effects and also the analgesic effects of opioids and can produce symptoms of acute narcotic withdrawal.

Reversal agents are convenient for procedural sedation areas but should not replace judgment in appropriate patient selection for sedation.

SEDATION-RELATED ADVERSE EVENTS

Overall, significant sedation-related adverse events are rare, estimated at less than 1% in most studies,^{3,11} and many can be avoided with careful patient selection. The lower rate of complications from the gastrointestinal literature compared to the Anesthesia Closed Claims Project⁵ data may reflect the changes in practice in many remote procedural locations—most advanced endoscopy suites now utilize anesthesia services to provide a full range of anesthesia from sedation and MAC to general anesthesia.

Respiratory depression, hypoxemia, and hypotension are the most common sedation-related adverse events during endoscopic procedures.^{1,7,11} Airway obstruction and hypoxemia are the most concerning adverse events during sedation and anesthesia, but fortunately, serious events are relatively uncommon. Airway obstruction can occur when a patient becomes relaxed and the musculature relaxes, leading to a constricted upper airway. Obstruction frequently responds to lightening the anesthesia if possible and providing a jaw thrust, tilting the chin or moving the head. Capnography can be particularly useful in detecting airway obstruction or apnea prior to the development of hypoxemia—especially in obese or difficult patients.

In routine screening colonoscopy, aspiration and micro-aspiration, identified as coughing, are uncommon, occurring in 0.1%–0.16% of colonoscopy cases, although this percentage appears to be higher in patients receiving propofol sedation versus traditional moderate sedation. This probably reflects the different sedative profiles: propofol has a narrow therapeutic window, and it is easy for a patient to rapidly become more sedated than planned, leading to increased relaxation of musculature and diminished cough reflex. The risk of aspiration during upper endoscopy is more significant, especially in patients with bowel obstruction, or those already vomiting. In these types of patients, a general anesthesia and endotracheal intubation are recommended.

Hypotension is frequently related to drug administration, and it is most pronounced during propofol sedation. Light sedation may conversely lead to hypertension and tachycardia. Hypotension during sedation frequently responds to administration of intravenous fluids, although occasionally a short-acting vasopressor might be needed. Bradycardia occasionally occurs as a result of a vagal reaction to the intraluminal stretching of the intestines during a colonoscopy. In most instances, just releasing some of the air is enough, if not atropine, an anticholinergic can be administered.

PROCEDURES

As mentioned, it is becoming more common for advanced endoscopic procedures to be performed with an anesthesia provider under deep sedation. A procedure such as endoscopic ultrasound evaluation of the esophagus and stomach and pancreas can be long, and patient cooperation is important especially if ultrasound-guided biopsies are anticipated. Endoscopic retrograde cholangiopancreatography can also be challenging and is generally performed in a semiprone or swimmer's position, making the airway more challenging. For these cases, bolsters placed under the chest can make the airway more accessible if a jaw thrust or suction is required. MAC anesthesia is frequently adequate, although occasionally, general anesthesia with general endotracheal

anesthesia may be required, especially in obese, ASA physical classification 4, and patients with pulmonary disease.^{12,13} Radiofrequency ablation or cryotherapy of the esophagus are examples of other therapeutic procedures performed in the advanced endoscopy suites that may require deep sedation.

Colonoscopy is the most common of all gastrointestinal procedures and can frequently be performed with moderate sedation, although deep sedation with propofol is becoming increasingly popular.^{1,3} Advantages of propofol over moderate sedation include greater relaxation, more rapid awakening after the procedure, and recall in the recovery areas. However, propofol sedation for colonoscopy can add to cost, and there is significant controversy surrounding the “right” choice of anesthesia for screening procedures.

In conclusion, appropriate sedation for endoscopic procedures will depend on both patient features and the characteristics of procedures. In general, most advanced endoscopic procedures should be done with an anesthesia provider to ensure that an appropriate level of anesthesia is achieved without additional patient risk.

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Diagnostic upper gastrointestinal endoscopy

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INTRODUCTION

Endoscopic evaluation of the upper gastrointestinal tract has evolved significantly over the last 50 years. The flexible endoscope first utilized in the 1960s required the endoscopist to peer through one end of the instrument, while relying on coherent fiber-optic cables to convey an image of the gastrointestinal tract at the opposite end. This provided the first minimally invasive approach to diagnostic evaluation of the foregut. Since then the development of high-resolution video endoscopy has allowed superior images to be projected for all participants in the procedure to see. Continued improvements in the endoscope have broadened the use of this instrument from a simple window into the gastrointestinal tract to a routinely used diagnostic, screening, and surveillance tool, which proffers a continually expanding platform for therapeutic intervention. With an already wide array of techniques available and newer procedures such as natural orifice surgery being employed, familiarity with the endoscope is a fundamental requisite skill for contemporary surgeons who wish to diagnose and treat foregut pathology in a minimally invasive fashion.⁸

INDICATIONS/CONTRAINDICATIONS

Upper gastrointestinal endoscopy is indicated for evaluation in patients with a variety of symptoms as well as known medical conditions. Dyspepsia, dysphagia, odynophagia, gastroesophageal reflux disease, as well as persistent nausea and vomiting are all reasons to consider diagnostic evaluation using endoscopy. Early endoscopy should be prioritized in some of these settings when associated with “alarm” symptoms, for example, those more likely to be associated with malignant processes. Included in this category would be patients with dysphagia, weight loss, or persistent vomiting in the absence of evident pathology beyond the foregut.

Other conditions associated with malignancy require careful surveillance. These include Barrett esophagus, familial adenomatous polyposis, and prior history of gastric ulcers or polyps. Situations such as gastrointestinal bleeding and ingestion of corrosives also warrant endoscopy to stratify risk, guide management decisions, and allow minimally invasive therapeutic intervention. This procedure is similarly useful for evaluation and treatment of varices in the portal hypertensive patient, and can provide access for small bowel biopsy in patients with malabsorptive disorders. Endoscopic evaluation of the foregut is also a useful adjunct in the operating room to guide intraoperative decision-making in difficult cases, or in function-restoring cases such as procedures for achalasia or gastroesophageal reflux disease³ (Table 5.1).

Both absolute and relative contraindications to upper gastrointestinal endoscopy exist. One absolute contraindication is the inability to tolerate the procedure or attendant sedation due to severe medical comorbidities. A suspected perforation may be worsened by insufflation and should also deter endoscopic evaluation, unless endoscopy will be critical to therapeutic decision-making or delivery. Other conditions such as Zenker diverticulum, uncorrected coagulopathy, and less severe comorbidities such as respiratory insufficiency or recent myocardial infarction may be relative contraindications, depending on the indications and clinical setting.³

TECHNIQUE

Preoperative preparation

When first evaluating a patient for upper endoscopy, several issues must be addressed. The indications and potential benefit of endoscopic evaluation should be reviewed for each individual patient, as comorbidities determine the associated

Table 5.1 Indications and contraindications to diagnostic upper endoscopy

Indications—Diagnostic

Dyspepsia
Dysphagia
Odynophagia
Gastroesophageal reflux disease
Nausea and vomiting

Indications—Surveillance

Barrett esophagus
Familial adenomatous polyposis
History of gastric ulcers or polyps

Indications—Miscellaneous

Bleeding
Corrosive ingestion
Varices
Malabsorption disorder
Intraoperative evaluation

Contraindications—Absolute

Inability to tolerate the procedure
Inability to tolerate sedation

Contraindications—Relative

Suspected perforation
Zenker diverticulum
Uncorrected coagulopathy
Less severe comorbidities

risk of complications and may dictate additional planning and preparation. While small-caliber nasal endoscopes may be used with local anesthesia alone in some diagnostic settings, most diagnostic and essentially all therapeutic esophagogastroduodenoscopy (EGD) is accomplished with conscious sedation or higher-level anesthesia. The need for sedation during the procedure dictates assessment of the patient's airway, American Society of Anesthesiologists (ASA) class, and comorbidities so that appropriate monitoring and anesthesia assistance are provided if higher-level sedation or airway management is required, so as to ensure patient safety. Continuous electrocardiographic and pulse oximetry as well as intermittent blood pressure monitoring are routinely employed, as the most common complications are cardiopulmonary and sedation related in nature. Capnography may also be very useful as a more sensitive indicator of respiratory depression related to sedation than pulse oximetry. The presence of significant airway impairment as judged by Mallampati classification (reference or picture) or other assessments, or attendant cardiac or pulmonary disease may dictate anesthesia involvement for closer peri-procedural monitoring and management. Coagulation disorders should also be identified and planned for accordingly. Management of anticoagulation issues peri-procedurally involves a risk-benefit analysis depending on the reasons for anticoagulation and expected procedural

risks and interventions.¹⁵ If a patient is taking anticoagulant medications, these should be held in the days prior to the procedure when such risk-benefit analysis justifies.⁵

On the day of the procedure, the patient should be instructed to take nothing by mouth for a period of 6–8 hours. Clear liquid intake closer to the procedural time in patients with normal foregut motility is likely permissible in line with ASA guidelines, if necessary.¹⁶ Patients with motility issues or gastric outlet obstruction may require a longer period without oral intake or lavage to achieve emptying of the stomach and decrease the need for repeat evaluations due to inadequate visualization. Preprocedural motility agents such as erythromycin may be helpful in such settings and have been shown to improve visualization in the setting of upper gastrointestinal bleeding.¹⁷ Additionally, if a patient wears dentures they should be removed at the time of the procedure. Mellinger–Sages antibiotics are currently recommended only in the setting of percutaneous gastrostomy tube placement, or intervention for bleeding in cirrhotic patients (starting at time of admission), as the risk of infection including endocarditis with diagnostic upper endoscopy is quite low.^{1,4}

As with any other invasive procedures, informed consent is an important step in preparing the patient for his or her endoscopic evaluation. The potential risks range from bleeding or infection to less likely but more devastating complications like perforation and must be disclosed in the preoperative setting. Because of their relative frequency compared to other complications, cardiopulmonary complications related to sedation should also be reviewed. Discussion of any therapeutic interventions being contemplated should be held beforehand as well, and the patient should have a chance to ask any questions. A more detailed discussion of procedure-related complications occurs later in this chapter.⁵

Equipment

The standard features of an upper endoscope include a control head, bending tip, and the intervening shaft, which is approximately 1 m in length. The control head is generally held in the left hand of the endoscopist. Buttons on the front are manipulated using the index and middle fingers and function as valves, which provide suction and air/water control. The two knobs on the side are turned using the thumb and allow angulation of the scope tip in four directions. The axis of the larger knob is referred to as “up and down” by convention, and the smaller knob moves “left and right.” The bending section is the distal 10 cm of the endoscope and deflects the tip 180° or more. The shaft of the endoscope houses channels for air or carbon dioxide insufflation, water, suctioning, and passage of instruments for biopsy or other therapeutic devices.^{2,12}

The endoscopic tower includes a light source, imaging processor, and irrigation bottle, and often includes a video screen. Other devices may also be housed on the tower, including units for thermal energy intervention and carbon dioxide insufflators.

Patient positioning

The patient is placed in the left lateral decubitus position facing the endoscopist for standard EGD. Supine position may be used in certain settings such as planned gastrotomy placement or intraoperative endoscopy. The head should be supported on a small pillow. Intravenous access is preferably obtained in the right upper extremity to allow easy access to the access site. A bite block is placed between the teeth to facilitate scope passage and prevent damage to the instrument during the procedure. Supplemental oxygen is provided via nasal cannula, and monitoring devices are attached to the patient. Elevating the head of the bed slightly and angling the neck so the mouth faces downward are maneuvers to minimize aspiration risk during the procedure. Sedating medications can be administered once the patient is appropriately positioned.^{6,7,9}

Passing the endoscope

Prior to insertion of the scope, the air, irrigation, suction, and image projection should all be tested so troubleshooting the equipment can occur prior to the start of the procedure. As the endoscopist awaits an appropriate level of sedation, he or she should position the scope in front of the patient and rehearse the tip angulation. The natural curvature of the scope and the position of the patient should be noted and can help in facilitating easy passage and manipulation of the scope. The tip should be well lubricated with water-soluble lubricant.

The end of the scope should be held in the right hand approximately 30 cm from the tip. This position allows passage of the scope without need for regripping before the cricopharyngeus muscle is negotiated, but avoids too much length, which can cause buckling and hinder attempts to intubate the upper esophagus. The axis of the bending portion should be positioned to move in the superior and inferior directions of the patient's midline. The tip is inserted while straight through the bite block over the tongue and then slowly angled inferiorly with the larger knob once the posterior pharynx is reached. Rehearsal of this movement prior to starting the procedure is useful and ensures proper alignment of the scope in the direction of the esophagus.

Once passage is initiated, the endoscopist should focus on the video screen projecting the endoscopic view. Gentle movements of the scope limit gagging and avoid tissue trauma. The larger knob should now manipulate movement of the tip in the anterior and posterior midline plane. By torquing the scope with the right hand, right and left movements can be easily performed. As the scope enters, orientation can be achieved by keeping the midline centered. The pale surface of the tongue will be anterior and the darker red palate will be seen posterior. The laryngeal cartilages and vocal cords should be identified anteriorly once past the epiglottis. Posteriorly, a small slit behind the arytenoid cartilages is seen and marks the esophageal opening. The piriform sinuses are also seen flanking each side of this opening.

Advancement of the scope posteriorly toward the esophageal opening is done gently. Asking the patient to swallow can help facilitate relaxation of the cricopharyngeal sphincter. The view through the scope may be obscured when this sphincter is closed against the scope tip. With gentle pressure while the patient swallows, the scope can be guided into the esophagus as the sphincter relaxes. This maneuver requires smooth, gentle movements, and the scope should only be advanced when minimal resistance is encountered and visualization remains adequate.^{6,9,12}

There are several other approaches that may be utilized to initially pass the endoscope. The commonly used technique under direct visualization described previously is typically adequate and optimal. Blind insertion can also be performed but is more commonly used with a side-viewing scope such as that used for endoscopic retrograde cholangiopancreatography (ERCP). This technique requires knowledge of anatomical landmarks and coordinates scope movements depending on the length of scope that has passed. Depending on the size of the patient, the cricopharyngeus is usually encountered around 15–18 cm from the incisors, and the patient is asked to swallow to facilitate scope passage. The endoscopist uses tactile feel to guide the tip in, and if resistance is encountered, must stop to avoid injury.

Some physicians use their fingers to assist in blind insertion. The second and third fingers are placed over the tongue to guide the scope over them into the posterior pharynx. The bite block is placed on the scope initially and then slid in place between the teeth once the scope has passed. Disadvantages of blind techniques include higher risk of iatrogenic injury and difficulty encouraging sedated patients to follow commands that aid in scope passage. Furthermore, if insertion is performed without the bite block in place, the patient may bite the scope or the physician's fingers.^{6,12}

STEPS OF DIAGNOSTIC EVALUATION

Once intubation of the esophagus is achieved, an evaluation of the upper gastrointestinal tract should be performed in a methodical approach to ensure thorough evaluation. The esophagus, stomach, and proximal duodenum are all inspected regardless of the inciting indication. As with initial intubation of the esophagus, manipulation of the scope should be gentle to avoid scope trauma to the mucosa, which may confound diagnosis or cause injury to the patient. Specific findings of common pathologies that may be seen on evaluation are described in the section "Common Pathology."

Esophagus

The esophagus is first evaluated as the endoscope is advanced downward and again at the end of the procedure while withdrawing the scope. The appearance of the mucosa of the esophagus should be noted. Peristalsis may occur, and insufflation of gas can be used to maintain an open lumen

to adequately visualize the entire esophagus. When the scope tip is at the level of a structure within the esophagus, its position can be measured by noting the length of scope passed in relation to the incisors. The gastroesophageal (GE) junction is generally encountered approximately 38–40 cm from the incisors. The site at which the pale mucosa of the esophagus meets the darker red mucosa of the stomach is the squamocolumnar junction and is referred to as the “Z line.” The hiatus of the diaphragm can be observed as a constriction of the esophagus during inspiration and normally is within 2 cm of this line. By asking the patient to sniff, this constriction appears more prominent.^{6,12}

Stomach

The stomach is evaluated once the scope is advanced past the GE junction. To facilitate relaxation of any torque on the scope, the right hand should let go of the endoscope, and the endoscopist should step back from the table, allowing the endoscope to straighten. With the patient in left lateral position, the scope should then orient so that the lesser curvature is at the 12 o'clock position and the greater curvature is at the 6 o'clock position in the visual field. The anterior stomach wall will be on the left and the posterior wall on the right. The cardia, fundus, body, and antrum are all inspected sequentially while insufflating to maintain an adequate view. Any pooled gastric contents should be suctioned so no lesions are missed, and the risk of reflux or aspiration is decreased. The mucosa, blood vessels, and gastric folds should be evaluated, and distensibility and peristalsis should be assessed. With the previously described orientation, the rugal folds should run parallel toward the pylorus. Once the pylorus is encountered, it can be intubated for further exploration of the duodenum. As the scope is backed away from the pylorus and antrum, the final step in evaluating the stomach is to retroflex and examine the hiatus. To obtain this view, the endoscope should be positioned in the antrum. The tip is then deflected upward using the thumb on the large knob, and the left hand is rotated 90° counterclockwise. With the scope in this position, the cardia is visualized, and the scope shaft can be withdrawn to achieve a closer view of the hiatus. Torque applied with the right hand allows circumferential visualization of all areas in the proximal stomach from this retroflexed position. Occasional fine adjustments of the smaller right/left knob may help with optimal visualization. The incisura is similarly best inspected from this position before allowing the endoscope to return to its fully straightened position.^{9,10}

Duodenum

Intubation of the pylorus allows inspection of the duodenum. The opening should be centered in the endoscopic view. It is easiest to manipulate the left and right movements with torque and up and down deflections with the

larger knob. In most patients, the scope can be easily passed through the pylorus. The surgeon may need to wait for a spasm to pass and advance only when the sphincter relaxes. If undue resistance is encountered, this may signify stenosis. It is helpful to avoid overdistention of the stomach when preparing to negotiate the pylorus, which may facilitate pyloric spasm. Occasionally a small burst of suction applied when the endoscope is peering through the pyloric opening may engender entry. It should also be remembered that some of the best viewing of the duodenal bulb may be accomplished through the pylorus, rather than after it has been passed.

When the scope is advanced into the duodenal bulb, the momentum usually propels it into the distal bulb. To evaluate this area, the scope must be backed out slowly with slight deflections of the tip to ensure all mucosa is inspected. Lesions in this area can be easily missed due to the propensity of the scope to slip back into the stomach, and particular care should be taken to visualize all aspects of the bulb. Passage of the scope into the distal duodenum is the next step and can be challenging due to the superior duodenal angle, depending on patient anatomy. This sharp turn connects the duodenal bulb to the descending duodenum and must be navigated to gain access to the remainder of the duodenum. As the duodenum sweeps posteriorly, the luminal view often disappears. To advance past this turn, the right hand should release the scope while the left hand manipulates the larger knob so the tip deflects slightly upward. Rotation of the left hand 90° clockwise facilitates negotiation of the angle into the descending duodenum. This is followed by pulling back on the scope, allowing paradoxical advancement into the more distal duodenum as the instrument moves from a looped, greater curve position in the stomach to a lesser curve and straightened position. Continued evaluation of the distal duodenum can be accomplished as desired by advancing the scope under direct luminal inspection. If recurrent looping in the stomach occurs and limits more distal duodenal intubation, gentle pressure on the epigastrium may help overcome this.⁹

WITHDRAWAL OF THE ENDOSCOPE

At the conclusion of the procedure, the endoscope should be straightened out and any air in the stomach should be suctioned. Desufflation decreases postprocedure discomfort related to gastric distension. It is important to reinspect all surfaces during scope withdrawal to ensure pathology is not missed. As the tip is backed out of the cardia into the esophagus, small amounts of gas may need to be instilled to maintain an open lumen for a final look at the esophageal mucosa. The right hand should slowly withdraw the scope. Fine movements with the larger knob and torque of the right hand should be used to keep the lumen centered as the scope is removed.¹²

SPECIMEN COLLECTION

During endoscopic evaluation, lesions may be identified that warrant biopsy of tissue for microscopic examination.

Specimens should be obtained using cupped forceps passed through the instrument insertion channel. Lesions should be centered in front of the endoscope. It is easiest to keep the forceps relatively close to the scope tip and approach the lesion by moving the scope instead of the forceps themselves, as fine control becomes more difficult when the forceps extend far beyond the tip of the endoscope. It is helpful to know that the suction and biopsy channel is at 6 o'clock on the endoscopic visual field, so positioning pathology or material to be suctioned in that location will facilitate the task. With the forceps in the open position, the jaws of the same should be pressed against the lesion, closed, and the forceps pulled back quickly to obtain the specimen. Some forceps are spiked, which allows multiple specimens to be taken and secured on the spike before withdrawing the biopsy forceps.

A few additional tissue sampling principles are useful to help ensure an appropriate piece of tissue is obtained to maximize the diagnostic yield. Ulcers should be biopsied at the rim in four quadrants. Biopsy of the center is usually only helpful if the sample will be used to identify a viral process. Neoplastic lesions may have necrotic portions, so if possible, avoid taking the biopsy from these areas as they lack the architecture to make an accurate histologic diagnosis. Esophageal lesions should be approached with the scope pressed against the wall and the forceps kept close to the tip of the scope. Submucosal lesions are difficult to sample with standard forceps. In such settings, biopsy-on-biopsy techniques may be utilized, or more advanced therapeutic tools such as endoscopic ultrasound-guided tissue acquisition, large particle biopsy, endoscopic mucosal resection, and endoscopic submucosal dissection may be considered. Advanced skills and equipment are required for these interventions.⁶

NORMAL FINDINGS

Mastery of the technique of upper gastrointestinal endoscopy along with knowledge of the expected normal appearance of foregut anatomy are necessary for successful diagnostic evaluation. Pictures of normal findings in the esophagus, stomach, and duodenum are provided in the following section (**Figures 5.1 through 5.6**).

The normal mucosa of the esophagus appears pink and smooth, and small vessels may be seen running longitudinally within the wall. The Z-line is a slightly irregular line where the pale esophageal mucosa meets the darker red stomach mucosa. The indentation of a normal hiatus with no hernia can be seen near the level of the Z-line.⁷

Normal stomach mucosal appearance varies considerably, and the color can range from pink to red to orange. Differences may result from the presence of bile or other gastric contents, which can alter the absorption of light, as can other physiologic conditions such as anemia. The endoscopist should be more cognizant of areas that are markedly different in appearance rather than the color itself. Gastric folds are more prominent in the greater curvature and should become less prominent with adequate insufflation.¹⁰

Normal findings on upper gastrointestinal endoscopy

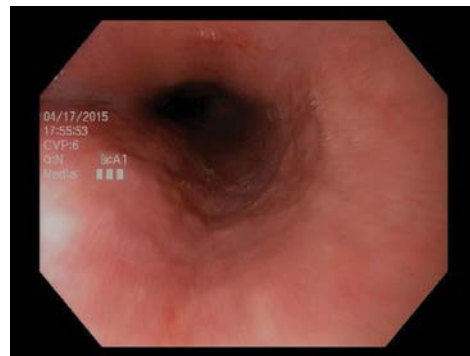


Figure 5.1 Esophagus—midportion of esophagus.

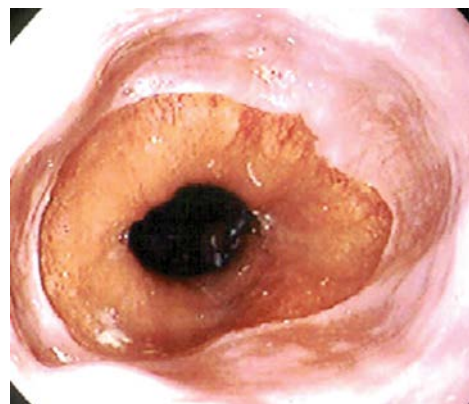


Figure 5.2 Esophagus—normal Z-line.

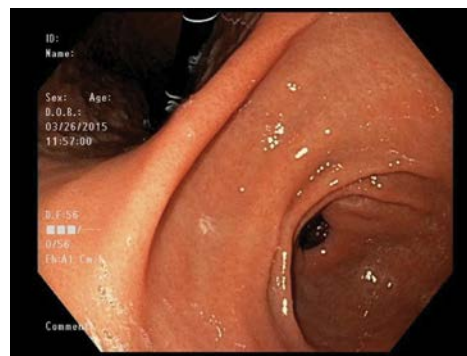


Figure 5.3 Stomach—retroflexed view demonstrating normal mucosa at the angularis or incisura.

Normal findings on upper gastrointestinal endoscopy (*Continued*)



Figure 5.4 Stomach—normal gastroesophageal junction on retroflexion with no hiatal hernia.

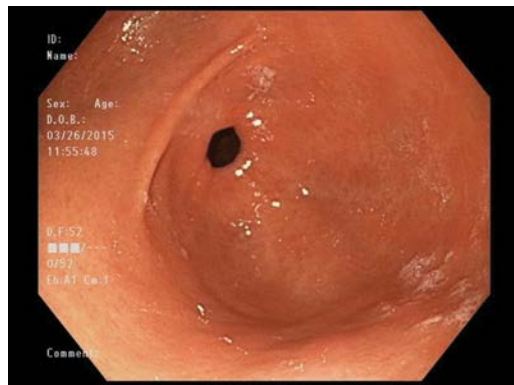


Figure 5.5 Stomach—antrum with view of pylorus.

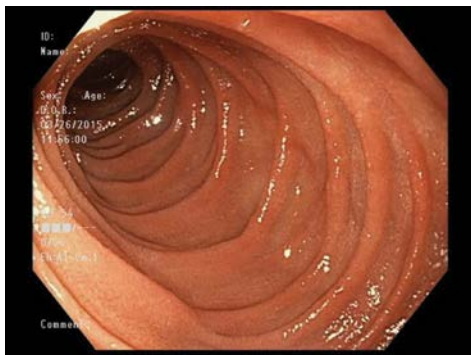


Figure 5.6 Duodenum—normal mucosa in the second portion of the duodenum.

The duodenal mucosa appears pale and granular. Small white nodules in the duodenal bulb typically signify ectopic gastric mucosa and/or Brunner glands, and are a normal finding. There are no folds in the bulb, and the first fold indicates the transition into the second portion of the duodenum. Fold architecture should be mildly prominent and smooth in the absence of underlying disease.⁷

COMMON PATHOLOGY

When performing diagnostic endoscopies, the physician will undoubtedly encounter a variety of abnormal findings. Recognition of common pathology is necessary. An endoscopist in training should profitably spend time with atlases of common and uncommon pathologies so that they may be recognized when encountered. Pictures and descriptions of common pathologic findings that should be recognized are depicted in [Figures 5.7 through 5.17](#).

Common pathology on upper gastrointestinal endoscopy



Figure 5.7 Esophagus—Barrett esophagus (intestinal metaplasia): lesion extends proximal to the Z-line as “tongues” of salmon-colored mucosa. Lesions may be circumferential or occur as “islands” above the squamocolumnar junction.



Figure 5.8 Esophagus—esophagitis: circumferential mucosal ulceration with peptic stricture.

Common pathology on upper gastrointestinal endoscopy (Continued)



Figure 5.9 Esophagus—esophageal neoplasm: exophytic mass projecting into the lumen of the esophagus, may appear nodular or have ulcerated areas.



Figure 5.12 Stomach—neoplasm: carcinoma or lymphoma range from polypoid masses to exophytic, ulcerated lesions.



Figure 5.10 Esophagus—ring: thin and symmetric circumferential projections that partially occlude the esophageal lumen.



Figure 5.13 Stomach—hiatal hernia: retroflexed view shows patulous gastroesophageal junction with a pouch of stomach above a ridge at the level of the diaphragmatic hiatus.

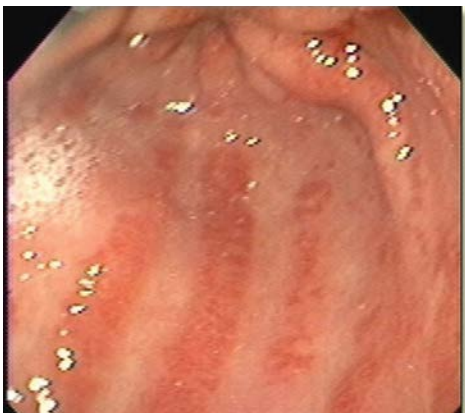


Figure 5.11 Stomach—gastric antral vascular ectasia.

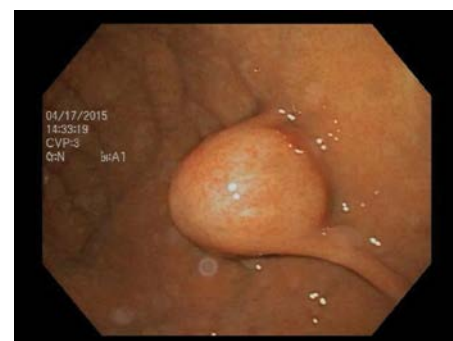


Figure 5.14 Stomach—gastrointestinal stromal tumor: mass emanating from beneath mucosal plane.

Common pathology on upper gastrointestinal endoscopy (*Continued*)

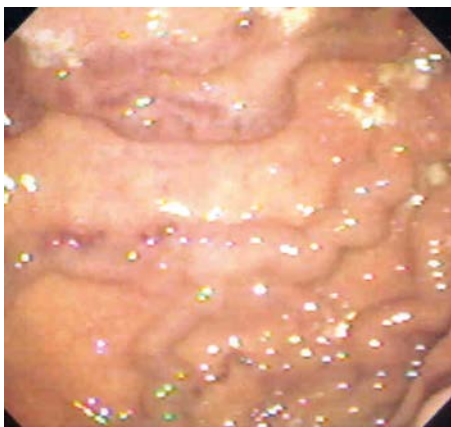


Figure 5.15 Stomach—gastric varices related to underlying portal hypertension.



Figure 5.16 Duodenum—ampullary mass: adenoma or cancer.



Figure 5.17 Duodenum—ulcer with arrow pointing to visible vessel.

COMPLICATIONS

Upper endoscopy is a relatively safe procedure, though it is not without risk. A variety of complications can result and range from mild to life-threatening.¹¹ The most feared adverse event is perforation. This occurs most frequently at the level of the cricopharyngeus and is associated with anatomic abnormalities including Zenker diverticulum, and difficult esophageal intubation. Perforation beyond the proximal esophagus is quite rare. This risk can increase, however, if therapeutic interventions are performed. Pulmonary aspiration may occur in patients with retained gastric contents either due to gastroparesis, gastric outlet obstruction, or active upper gastrointestinal bleeding. Though a transient postprocedure bacteremia can occur, infection is rare, and unless percutaneous gastrostomy tube placement is planned or the patient is a known cirrhotic with bleeding, antibiotics are not routinely administered preoperatively. The incidence of endocarditis from diagnostic upper endoscopy is extremely rare. There is also potential for infectious entities including *Helicobacter pylori* or hepatitis to be spread from a contaminated endoscope or accessory, necessitating meticulous disinfection of all instruments. While not germane to typical diagnostic EGD, the potential for side-viewing duodenoscopes such as are commonly used for ERCP to harbor resistant organisms in the elevator assembly of the biopsy channel has been a recent area of significant public health concern.¹⁸ Bleeding, as with any procedure, is always a potential risk, particularly when tissue sampling or intervention is required, and especially so in patients with coagulopathy. Other issues that may arise include hypoxia and cardiac dysrhythmia, which make careful monitoring throughout the procedure imperative.^{5,13}

EDUCATION

Upper gastrointestinal endoscopy is an essential diagnostic tool for evaluating the foregut. Contemporary surgical and nonsurgical interventionalists are increasingly employing less-invasive methods of treating surgical diseases. Endoscopic skill not only provides the foregut surgeon with a necessary tool for diagnosis, including tissue acquisition, but has become a truly requisite interventional skill as intraluminal approaches replace standard operative options for treatment of many conditions that commonly present in their practices. Examples of such transitions included dysplastic Barrett epithelium, achalasia, bleeding peptic and portal hypertensive diatheses, esophageal perforation, and some forms of reflux disease. Intraoperative endoscopy has also become critical in performing even standard foregut surgery, including fundoplication and esophageal myotomy. Recognizing the utility of proficiency in this arena, educators through the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) have developed a curriculum and examination

process to ensure surgical trainees demonstrate basic competency with this technology. The Fundamentals of Endoscopic Surgery (FES) program was put forth as a way to confirm new surgeons entering the workforce possess basic knowledge and technical skills needed to provide safe and appropriate gastrointestinal patient care. The American Board of Surgery (ABS) now requires current trainees (beginning with 2018 general surgery residency graduates) to have FES certification for board eligibility, attesting to the fundamental nature of endoscopy training for the field of gastrointestinal surgery.¹⁴

CONCLUSION

Upper endoscopy is a commonly performed procedure utilized for a broad range of indications. A methodical approach preparatory and technical approach, along with knowledge of both normal and common pathologic findings, is necessary for accurate diagnosis and management of foregut disease. EGD is a relatively safe procedure, which provides valuable information including the opportunity for tissue diagnosis. Its use for therapeutic intervention continues to expand, and mastery of this skill is necessary for the gastrointestinal interventionist of the present and the future.

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Diagnostic upper endoscopy II: Endoscopic ultrasound

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INTRODUCTION

Esophageal ultrasound (EUS) was introduced into clinical medicine in the late 1980s. At that time it was primarily a diagnostic procedure. Over the last several decades, it has evolved into an important tool in the armamentarium of gastroenterologists, surgeons, and oncologists.

The original echoendoscopes incorporated radial mechanical transducers. These instruments were useful for examining lesions in the upper gastrointestinal (UGI) tract and had a limited role in the evaluation of the pancreas. Over time instrumentation has evolved into more sophisticated devices. The echoendoscopes are now composed of electronic transducers. There are three types of instruments available: radial echoendoscopes, linear echoendoscopes, and probe ultrasound (US) devices.

The indications have developed over time from routine staging and evaluation of subepithelial lesions to therapeutic interventions. The accessories for EUS have evolved over time to allow for therapeutic interventions.

ROLE OF ENDOSCOPIC ULTRASOUND

Evaluation of subepithelial lesions of the upper gastrointestinal tract

Subepithelial lesions of the UGI tract are a common finding during routine esophagogastroduodenoscopy (EGD). The most common site of occurrence is within the stomach, but lesions are also seen in the colon, esophagus, and duodenum.¹ A majority of subepithelial lesions are benign when diagnosed; however, several of these lesions have a potential for malignant transformation.²

Subepithelial lesions are often an incidental finding and are unrelated to the indication for which the patient is undergoing an endoscopic examination.³

Imaging studies such as computed tomography (CT) and magnetic resonance imaging (MRI) are not sensitive enough to discover these lesions owing to their small size.

EUS is the gold standard for evaluation of subepithelial lesions, as it affords the following benefits: ability to differentiate extramural compression from intramural growth, determine layer of origin, accurately size the lesion, evaluate for regional lymphadenopathy, obtain tissue for diagnosis, and help determine appropriate management and follow-up.⁴

EUS imaging of the gastrointestinal (GI) tract is characterized by five layers that approximate but do not directly correlate to the histological layers: layer (1) mucosal interface; layer (2) muscularis mucosae; layer (3) submucosa plus the acoustical interface between the submucosa and the muscularis propria; layer (4) muscularis propria minus the acoustical interface between the submucosa and the muscularis propria; and layer (5) serosa and subserosal fat.⁵⁻⁷

An algorithmic approach has been suggested to approach such lesions, and it is based on the size on the initial EGD. If a lesion is less than 1 cm, a biopsy should be taken and repeat EGD should be done in a year to reevaluate. If a lesion is greater than 1 cm, an EUS should be done initially to further characterize the lesion, look for any signs of malignancy, and also to acquire tissue for diagnosis.^{3,4}

Staging cancer

EUS has become an increasingly important diagnostic tool in the staging of carcinomas. The accuracy in staging cancers is a vital step for the guidance of treatment options.

ESOPHAGEAL CANCER

Esophageal cancer is the fifth most common GI cancer in the United States.

EUS provides a detailed view of the esophageal wall. It helps determine the depth of the tumor. EUS assists in the differentiation of benign and malignant lymph nodes. EUS is the most accurate modality for regional staging of esophageal cancer.

The role of EUS in the initial diagnosis of esophageal cancer is limited to cases in which the initial endoscopy fails to make a diagnosis.⁸ An example would be in a patient with pseudoachalasia, the lesion may be subepithelial.

EUS with or without fine needle aspiration (FNA) is typically performed if the biopsies or brush cytology during the initial endoscopy are nondiagnostic and there is high clinical suspicion for malignancy.⁹

EUS plays only a limited role in the detection of metastatic disease and restaging after neoadjuvant therapy.

GASTRIC CANCER

The gold standard for diagnosing gastric cancer is standard upper endoscopy with biopsy.¹⁰ The staging workup should begin with noninvasive imaging studies such as CT and possibly MRI. EUS is not recommended before these studies, unless it is available at the time of the initial endoscopy. Detection of any unresectable disease or metastasis eliminates the need for EUS evaluation.

EUS evaluation of gastric cancer can be performed with EUS endoscopes or with a probe. The T staging increases in accuracy when high-frequency US probes (20 MHz) are used.¹¹ The echoendoscopes are more useful in evaluation of lymph nodes and blood vessel involvement. Accuracy rates of as high as 92% have been reported when both endoscopic appearance and EUS findings are used together for tumor classification.¹²

A recently published Cochrane review of 66 studies concluded that EUS has high accuracy for the diagnosis of gastric cancer, although the authors advised caution while interpreting the results due to large heterogeneity observed in the review.¹³

PANCREATIC CANCER

Pancreatic cancer is the second most common GI cancer in the United States. It is the fourth leading cause of cancer-related deaths in the United States.¹⁴

Over the last few decades, EUS has gradually become the method of choice for diagnosis and local treatment of pancreatic cancer. Radial and linear echoendoscopes are similar in efficacy for diagnosing and staging pancreatic cancer.¹⁵

When compared with CT or abdominal US-guided procedures, interventional EUS provides a more comprehensive real-time image and a shorter puncture pathway.

The present literature demonstrates that EUS-guided fine needle injection (EUS-FNI) is a feasible and safe procedure for treating pancreatic cancer.

Interventional EUS includes antitumor agent delivery, radiofrequency ablation (RFA), photodynamic drugs, radioactive seeds, celiac neurolysis, and placement of fiducial markers for image-guided radiotherapy (CyberKnife).

LUNG CANCER

The endoscopic approach to the diagnosis and staging of lung cancer has some advantages over conventional methods—it is less invasive than the surgical staging techniques, and it can provide a pathological diagnosis when compared to imaging studies. Endobronchial US-guided transbronchial needle aspiration (EBUS-TBNA) and esophageal US-guided fine needle aspiration (EUS-FNA) are complementary techniques. These procedures are being increasingly used as alternatives to surgical staging.^{16,17}

The latest guidelines recommend that endosonography can be used as the first-line approach for diagnosis as well as staging of suspected and proven lung cancer owing to its high accuracy to detect lymph node metastases.^{18,19}

Hence, surgical exploration can be avoided in a large number of patients who require staging. However, it is still recommended that negative findings by EUS-FNA or EBUS-TBNA should be confirmed by surgical techniques.

Evaluation of pancreatic cysts

Pancreatic cystic lesions are being identified more frequently with the liberal use of cross-sectional imaging studies. It is estimated that 5%–15% of imaging studies demonstrate pancreatic cysts. PCLs can be classified on the basis of imaging morphological features into the following: (1) unilocular (pseudocysts, intraductal papillary mucinous neoplasms [IPMNs], unilocular macrocystic serous cystadenoma, and lymphoepithelial cysts); (2) microcystic (serous cystic neoplasms); (3) macrocystic (mucinous cystic neoplasms [MCNs] and IPMNs); and (4) cysts with a solid component (MCNs, IPMNs, cystic neuroendocrine neoplasms, solid-pseudopapillary neoplasms, ductal adenocarcinoma with cystic degeneration, and metastasis).^{20,21}

The most commonly used diagnostic tool for detection of PCLs is CT, owing to its widespread availability and ability to detect cystic lesions.²² The use of MRI with magnetic resonance cholangiopancreatography (MRCP) is an important tool to demonstrate the relationship between a PCL and the pancreatic duct.²⁰

The advantage of EUS stems from the fact that the morphology of the cyst can be clearly identified. In addition, a specimen of the fluid can be obtained for biochemical and cytologic analysis. These specimens assist in the diagnosis of PCL.

EUS findings that are typical of serous cystic neoplasms include multiple small, anechoic areas and thin septations.²³ MCNs are visualized as fluid-filled, thin-walled, septated cavities.²⁴ IPMNs in EUS demonstrate the dilation of the main pancreatic duct or branch duct with or without mural nodules and intraluminal contents.²⁵

EQUIPMENT

Echoendoscopes are composed of a US transducer that is embedded into the tip of an endoscope. The transducer is usually mounted in front of the optic lens. These echoendoscopes are similar to the standard endoscopes, but with a larger-sized tip and insertion tube to accommodate the US component. They are available in two different designs, radial and curvilinear, depending on the orientation of the transducer.²⁶

On the basis of the ability to position the transducer in close proximity to the target tissue, US imaging is able to define five acoustic layers in the GI wall that correspond to histologic layers of the mucosa, deep mucosa, submucosa, muscularis propria, and serosa or surrounding adventitia. Extramural structures, such as lymph nodes, blood vessels, ganglia, and solid intra-abdominal organs, are seen. In addition, the endoscope can maneuver in unique imaging planes and remove intraluminal air, which often obscures imaging during transcutaneous US.²⁷

Acoustic contact between the wall of the GI tract and the US probe are typically obtained through a water-filled balloon that surrounds the probe. Less frequently, this is accomplished by filling the GI lumen with water. Samples can be obtained effectively from small lesions irrespective of the organ affected. Tumors less than 5 mm in diameter can be detected and sampled by the use of high-resolution echoendoscopes with FNA or core biopsy needles.^{26,27}

Radial echoendoscope

A radial scanning echoendoscope produces a 360° real-time view perpendicular to the shaft of the echoendoscope.²⁶

Linear echoendoscope

Linear echoendoscopes produce real-time US images parallel to the shaft of the insertion tube, which are usually in a sector between 100° and 180°.²⁶

This orientation of the US image with the linear instrument facilitates visualization of the entire length of the needle during EUS-FNA. This is advantageous over the radial echoendoscope, which only shows a cross section of the needle, at the point where the needle crosses the imaging plane. Hence, all EUS-FNAs are done using the linear echoendoscope.²⁸

Probe

EUS probes are useful adjuncts to US of the GI tract. The probes are mechanical transducers and are placed via the accessory channel of an endoscope. These probes can be used to evaluate lesions in the esophagus, stomach, duodenum, colon, and pancreaticobiliary tree. The probes have a fixed frequency and are available in 12 and 20 MHz sizes.

The probes can be used to evaluate benign and malignant processes. Submucosal lesions in the luminal GI tract are the most frequently evaluated structures. Evaluation of obstructing tumors can be evaluated with EUS probes when echoendoscopes cannot be inserted.²⁹

THERAPEUTIC ENDOSCOPIC ULTRASOUND

Fine needle aspiration

EUS-FNA is a technique that permits the analysis of cells obtained through the puncture of various locations in the GI tract.³⁰ It was introduced for the first time in 1992 by Vilmann et al., who used it for the diagnosis of pancreatic masses.³¹ The advances in EUS since then have expanded the use of EUS-FNA from diagnosis of various diseases to therapeutic drainage and injections. EUS-FNA has greatly increased the diagnostic yield in patients undergoing EUS, and there have been reports suggestive of treatment changes in as many as 25% of patients with malignancy.³² EUS-FNA has been reported to have a sensitivity of about 80%–90% and specificity of around 85%–100%.³³

The most important principle for EUS-FNA use is to acquire the information that would potentially affect patient management, like differentiating between benign and malignant disease, staging of cancer, and histological evidence of malignancy.³⁴

As per the recent guidelines, EUS-FNA is currently recommended for sampling of the pancreas, esophagus, lung, lymph nodes in the mediastinum and abdomen, submucosal tumors, liver masses, and some left-sided adrenal masses.^{33,34}

Core biopsy

EUS-guided core biopsy was introduced to overcome the limitations of EUS-FNA in terms of sensitivity for the diagnosis of GI subepithelial lesions.³⁵ There are two types of core biopsy needles that are currently available: a 19-gauge ProCore biopsy needle (Wilson-Cook Inc., Winston-Salem, North Carolina)³⁶ and a 25- and 22-gauge SharkCore biopsy needle (Beacon Endoscopic, Newton, Massachusetts).

The advantage of these needles is that they provide a core of the tissue from which individual cell morphology can be easily seen. It can also be examined histologically for any architectural changes. A recent retrospective study showed the clinical impact of the Tru-Cut needle by demonstrating that treatment plans for 27% of the patients were changed with its usage.³⁷

The unique design of these needles helps to obtain both cytology and histology using reverse bevel technology, aiming for diagnosis on a decreased number of passes. A recent study showed that the diagnostic accuracy with the use of the ProCore needle was greater than 90%.³⁸

Pancreatic pseudocyst

A pseudocyst is a circumscribed collection of pancreatic enzymes, blood, and necrotic tissues. It is distinguished from a true cyst by the fact that the cyst lacks an epithelial layer—it is lined by granulation tissue. Pseudocysts are typically complications of acute or chronic pancreatitis.³⁹

EUS technique can be used to diagnose and manage pancreatic pseudocysts. There are several advantages of EUS-guided drainage of the pseudocyst: (1) it is less invasive and (2) there is a lower complication rate when compared to percutaneous drainage. EUS provides real-time visualization of the pseudocyst. Interposed blood vessels can be identified by Doppler US, thereby decreasing bleeding rates.^{21,40}

EUS-guided pseudocyst drainage has been shown to have a treatment success rate ranging from 82% to 100%.^{21,41,42}

A recent randomized controlled trial showed no difference in treatment efficacy between surgical and endoscopic treatment of pseudocysts. Endoscopic treatment, however, was associated with shorter hospital stays, better physical and mental health of patients, and lower cost.⁴³

Pancreatic necrosis

Pancreatic necrosis is a complex problem that requires a multidisciplinary approach. The indications for drainage of pancreatic necrosis include intractable pain, obstruction of the stomach or bile duct, and infected walled-off necrosis.^{44,45} It was treated with open pancreatic necrosectomy until recently, but this approach is associated with significant morbidity, mortality, and prolonged hospitalization.

EUS-guided treatment is advantageous as it helps in imaging the necrosis, confirms adherence of the cavity to the gastric wall, and demonstrates the absence of intervening vessels in the lumen prior to puncture.

Success rates of up to 95% have been reported, demonstrating the safety and efficacy of this minimally invasive procedure as an alternative to surgery.⁴⁶

Fiducial placement

Radiotherapy is an important treatment modality for patients with several types of cancer in the pancreas. It is essential for the target organs to be visualized properly during radiotherapy treatment. Since most of the organs are made of soft tissue, bony landmarks are usually used as a surrogate marker to localize the organs. But organs move relative to the bony landmarks; therefore, static points are preferred to improve the delivery of radiotherapy to patients with cancer.⁴⁷

A fiducial marker or fiducial is an object used as a point of reference in external beam radiation therapy. Fiducials are cylindrical gold seeds measuring 3–5 mm in length and 0.8–1.2 mm in diameter.⁴⁸

Several studies have reported technical success rates of as high as 88%–100% for EUS-guided fiducial placement.^{49–51} The technique of fiducial placement involves loading a gold seed into a 19-gauge needle. EUS is used to identify the lesion, and the needle punctures the tumor. This technique is repeated such that three or four markers are placed in a nonlinear sequence adjacent to the tumor.^{49,52,53}

Celiac plexus neurolysis

Patients with advanced pancreatic cancer may develop debilitating abdominal pain.⁵⁴ It is due to the invasion of the celiac plexus, which receives nociceptive stimuli from the pancreas.⁵⁵

Celiac plexus neurolysis (CPN) is a chemical ablation of the celiac plexus that can be used to treat this pain. It refers to the permanent destruction of nerve endings using phenol- and alcohol-based solutions, leading to the inhibition of the ascending pain information.

Wiersema et al. described EUS-CPN for the first time in 1996, in which they used bupivacaine and 98% alcohol for ablation of the celiac plexus.⁵⁶ They reported significant improvement in pain scores at 12 weeks postprocedure. A fairly recent randomized double-blinded controlled trial showed significant improvement in pain relief 3 months post-EUS-CPN.⁵⁷

Since then, it has become a recommended treatment for cancer-related pain. National Comprehensive Cancer Network (NCCN) guidelines recommend EUS-CPN for the treatment of severe cancer-associated pain.⁵⁸

Pancreatic cyst ablation

Pancreatic cyst ablation is another therapeutic application of EUS. Under EUS guidance, a PCL is punctured, aspirated, and injected with an ablative agent. This agent is cytotoxic to the cyst epithelium causing its destruction.⁵⁹

Ethanol was the first cytotoxic agent to be used for this purpose. An initial prospective pilot study used increasing concentrations of ethanol up to 80% for EUS-guided cyst ablation, and complete resolution was reported in only 35% of the cases.⁶⁰

EUS-guided ethanol lavage with paclitaxel injection (EUS-ELPI) for pancreatic cysts has been recently introduced. The cyst is first aspirated under EUS guidance, 99% ethanol is then used to lavage, and finally paclitaxel is injected into the cyst.⁶¹

A larger prospective study for EUS-ELPI for PCLs was reported in 2011. There were 52 patients in the study, out of which 29 (62%) of them showed complete resolution of the cysts.⁶²

Injection of chemotherapy

Pancreatic cancer is characterized by an abundance of desmoplasia and exhibits a hypovascular nature leading to poor

drug delivery. EUS-FNIs of antitumor agents adequately address this issue.

Presently, several novel therapeutic agents and techniques delivered through EUS-FNI are used in clinical trials to treat advanced pancreatic cancer.

Gemcitabine shows improvement over 5-fluorouracil in patients with unresectable disease. In 2011, Levy et al. reported EUS-FNI of gemcitabine in patients with unresectable pancreatic cancer. The survival rates at 6 months and 1 year were 76% and 46%, respectively.⁶³

OncoGel (ReGel/paclitaxel) is a new intralesional injectable formulation of the chemotherapeutic drug paclitaxel. The drug is mixed with a thermosensitive, biodegradable polymer, which allows for a slow, continuous release of the drug for up to 6 weeks. EUS-guided delivery of OncoGel into a porcine pancreas model has already been demonstrated.⁶⁴

Future of endoscopic ultrasound

BILIARY DRAINAGE

EUS-guided biliary drainage (EUS-BD) is an excellent alternative to percutaneous transhepatic biliary drainage or surgery for the management of biliary obstruction after unsuccessful endoscopic retrograde cholangiopancreatography.⁶⁵

The generally accepted indications for EUS-BD include the following: (1) failure of conventional endoscopic retrograde cholangiopancreatography, (2) altered anatomy, (3) tumor preventing access into the biliary tree, and (4) contraindication to percutaneous access such as large ascites.⁶⁶

OBESITY TREATMENT

EUS has been shown to be useful in the treatment of obesity. A pilot study done in 2008 showed that EUS-guided injections of botulinum toxin can be safely achieved with minimal adverse effects. However, the study was small and included only 10 subjects.⁶⁷

A recent meta-analysis of eight randomized and non-randomized studies concluded that intragastric botulinum toxin injection is effective for the treatment of obesity; however, there was significant heterogeneity in the methodology of the included studies.⁶⁸

CONTRAST-ENHANCED ENDOSCOPIC ULTRASOUND

Contrast agents are the newest adjuvant tools in the field of US. They are microbubbles consisting of gas encapsulated by a phospholipid or a lipid membrane.⁶⁹

Administration of these contrast agents intravenously enhances the EUS images by depicting the vasculature of the abdominal organs. Therefore, clear differentiation of vascular-rich and hypovascular areas is possible by using contrast-enhanced diffusion-EUS.^{70,71}

With the development of contrast-enhanced harmonic EUS, it is possible to better differentiate the tissue for more accurate classification.^{72,73}

SUMMARY

EUS was first introduced in the early 1990s as a diagnostic tool in the evaluation of subepithelial lesions, cancer staging, and evaluation of pancreatic cysts. In the ensuing 20 years, it has become a routine tool for gastroenterologists. Endoscopic diagnosis and therapy is routinely performed with EUS. The future of EUS is full of promise with new technologies on the horizon.

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Dilatation and stenting

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INTRODUCTION

Esophageal stenosis can arise from a multitude of conditions from malignancies to more benign conditions like gastroesophageal reflux disease, caustic ingestion, and anastomotic complications. Endoscopy is the standard approach to the treatment of these strictures, with dilation and stenting being the most common tools employed. This chapter presents a discussion of evolution of dilation and stenting along with current recommendations and indications for use.

DILATION

The concept of esophageal dilation is not new, having its origins in the Middle Ages. The original dilators were used as a technique of disimpaction of food boluses that had become lodged in the esophagus by pushing them distally.¹ The uses for dilators have expanded significantly, powered by the relatively low complication and high success rates.

Dilation is first-line treatment for many benign conditions including peptic strictures from reflux disease, radiation- or caustic-induced strictures, anastomotic strictures, and dysmotility conditions like achalasia and esophageal spasm. The most common presenting symptom is dysphagia, and unlike malignant strictures, weight loss is not typical. Dilation has a high success rate with 80%–90% of patients reporting symptom relief.² Unfortunately, up to a third of these patients will have recurrent symptoms within a year.²

TYPES OF DILATORS

There are essentially two different conceptual approaches to dilation with multiple dilator styles available within these approaches. The first is push dilation, which utilizes both an axial sheer stress and a radial stress to obtain adequate

luminal expansion. This class of dilators is frequently generically referred to as bougie dilators. The original weighted dilators were mercury filled, but given the concern for the safety of mercury spillage and waste management, most of these dilators have been transitioned to tungsten filled. The tip of the dilator can be in a tapered (Maloney) or blunt (Hurst) style (Figure 7.1). Weighted dilators are frequently



Figure 7.1 Maloney (red) and Hurst (blue) tipped push dilators.



Figure 7.2 Savary dilator.

delivered blindly. The second type of push dilator is an over-the-wire dilator. The polyvinyl Savary-Gillard dilators are the most common of this style used in the United States (**Figure 7.2**). They are typically used in conjunction with an upper endoscopy where the wire is placed through the working port of the endoscope. Once its location beyond the distal stricture margin is confirmed, the endoscope is removed and the dilators are passed blindly over the wire.

Since both types of push dilation are performed without direct visualization, pre-procedure sizing and feel for resistance are essential. Sizing can be accomplished with either pre-procedure imaging or endoscopy. The goal is to feel mild resistance when the dilator is passed, and a small amount of blood should be seen on postdilation endoscopy.

The second major approach is balloon dilation, which uses either pneumatic or hydrostatic pressure to produce a radial force against the stricture. There is no longitudinal shear force employed with balloon dilation. Balloon dilators can be used in an over-the-wire or through-scope fashion. The balloon can also be filled with a mix of contrast material and the dilation monitored with the assistance of fluoroscopy (**Figure 7.3**).

TECHNIQUE

For a dilation to be safely performed, appropriate pre-procedure assessment must be performed. First, esophageal



Figure 7.3 Balloon dilator with insufflator.

dilations require a technician with advanced endoscopic skills. An English study showed that endoscopists with less than 500 cases have a four times higher perforation rate than more experienced technicians.^{1,3} The nature of the stricture must be investigated with a thorough history, endoscopy, and possibly a swallow study, especially if the stricture cannot be traversed with the endoscope.¹ Any mucosal abnormalities should be biopsied to rule out underlying malignancy. Any concern for and underlying dysmotility syndrome should be appropriately evaluated with motility studies.

It is advisable to have the patient discontinue all anticoagulation and antiplatelet therapy prior to dilation to minimize the risk of difficult to control bleeding. We recommend checking a prothrombin time/international normalized ratio prior to initiating the procedure. The role of antibiotics in an endoscopic dilation procedure has been discussed in the literature, given the theoretical risk of exposing micro tears to endogenous bacteria. There are no data to suggest any benefit for prophylactic antibiotic administration in upper endoscopy patients, and current American Society for Gastrointestinal Endoscopy (ASGE) recommendations are against pre-procedure prophylaxis, even for patients with prosthetic heart valves.⁴

The dilation technique depends on the type of dilator being used and the nature of the stricture, but all dilations require consideration of a few basic principles. First is determining the final endoluminal diameter that is desired. It is

generally believed that a diameter of at least 13 mm should be achieved to ensure resolution of dysphagia in benign strictures.¹ This rule does not apply to bariatric anastomosis strictures where a smaller-diameter lumen is desired for appropriate weight loss. In the case of malignant strictures, less aggressive dilation is typically employed given the greater risk of perforation.

This is not to say that the goal diameter should be achieved with the first dilation. Often, serial dilations are required to obtain the desired final diameter. It is generally recommended that the initial dilation be roughly the same size as the stricture. Traditional dogma states that the endoscopist should follow the “rule of three,” in which no more than three progressively larger dilators should be used at a time.⁵ This belief was based on data from Savary dilators and may not be as important for balloon dilators, though further studies are needed.

The second decision to be made involves the type of dilator used. There has been substantial debate regarding the preferred dilator: push versus balloon. Though each camp has its supporters and small studies with differing evidence, no large study has shown a difference in regard to success or complication rates when comparing the types of dilators.⁶ It is our recommendation that the endoscopist use the device he or she is most comfortable with and clinical judgment for type of stricture being treated.

A weighted dilator is used with a blind technique. Preoperative imaging and endoscopy are used to determine the size of the stricture (both diameter and length) as well as its location. The dilator is then passed beyond the level of the stricture, using tactile response to resistance as a guide. Endoscopy should be done immediately following the dilation confirming the presence of a small amount of blood as expected in an adequate dilation and no perforation.

A balloon dilator, as discussed, uses only radial force to achieve stricture relief. An appropriate size balloon is determined, and the catheter is passed until the balloon is seated with the stricture at its center. The balloon is then inflated slowly with increasing atmospheres of pressure correlating to distinct diameters. A single balloon can be inflated to the three sequential diameters to fulfill the “rule of three” without having to exchange for larger balloons (Figure 7.4).

A third principle involves whether or not to use a guide-wire. Guidance wires assist in safely directing the dilator past the stricture, with the goal of minimizing complications, especially perforations. It also plays a significant role in the dilation of strictures where the endoscope cannot be advanced beyond the stricture. The wire is advanced a minimum of 20 cm past the stricture, and either the weighted or balloon dilator is passed over the wire. After a minimal dilation, the endoscope can traverse the stricture and evaluate the remaining esophagus and stomach.

The final principle to be determined prior to intervention is the use of fluoroscopy. Radiographic imaging can be used in conjunction with both push and balloon dilators. Wire location can be confirmed before the dilator is passed and

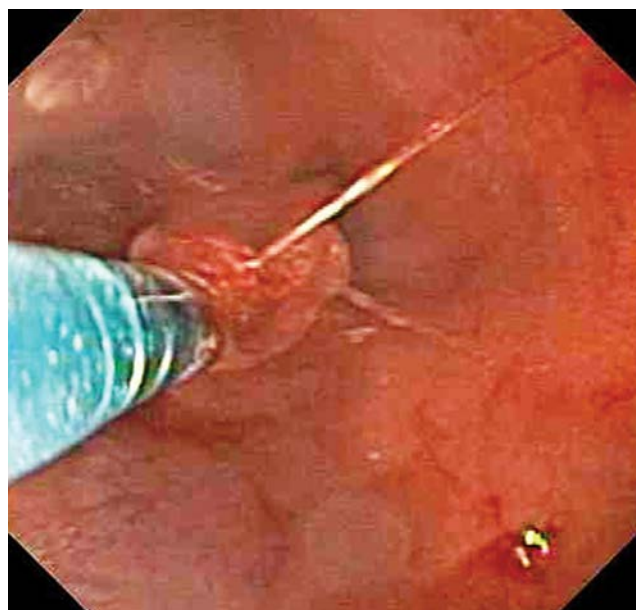


Figure 7.4 Through the scope balloon dilator.

the actual dilation observed in real time. With a Savary dilator, fluoroscopy can be used to observe the tapered portion of the dilator extending beyond the stricture so that the full diameter of the tool is utilized in the dilation.

With a balloon dilator, a 50:50 mixture of radiopaque contrast and saline can be used to fill the balloon. The stricture is localized to the midpoint of the balloon. As the balloon is expanded, authors recommend seeing the “waist” of the stricture indented on the balloon. Elimination of this indentation is used as confirmation that adequate dilation has been achieved.

COMPLICATIONS

Complications of esophageal perforation are rare, but their effects can be devastating. The most feared complication is perforation, with reported rates in the literature ranging from 0.5%–1% for benign stricture and as high as 6%–7% in malignant strictures.^{1,7} There is a reported increased risk of perforation when the procedure is performed by an inexperienced endoscopist and when dilators are passed blindly. Other major complications include bleeding and pulmonary aspiration.

STENTING

When dilation of esophageal strictures fails, esophageal stenting is generally considered to be the second-line treatment. Esophageal stents were originally developed for treatment of dysphagia from malignant strictures. These stents were quite different from those used today. They were composed of rigid plastic with very high complication rates.⁸

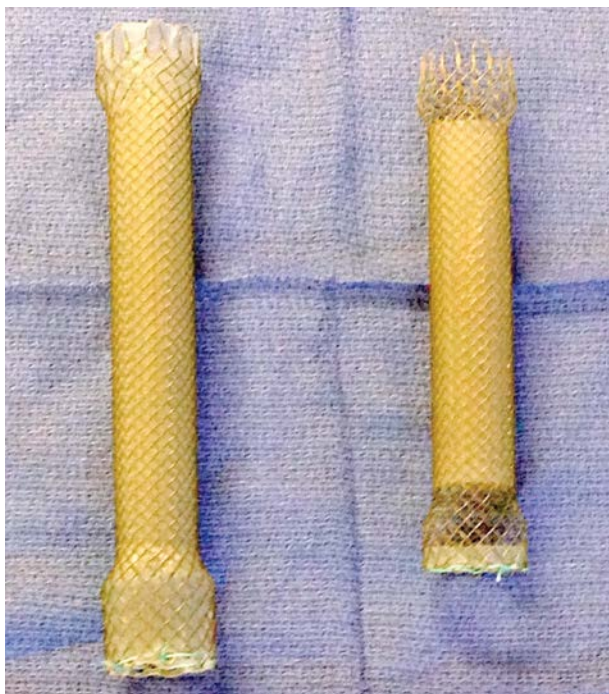


Figure 7.5 Fully covered and partially covered stents.

Use of self-expanding metal stents (SEMSs) began in the 1990s and initially consisted of bare metal stents. Still being used mainly for malignant pathology, these were uncovered metal stents with the intention of permanent palliation. Unfortunately, bare metal stents have a high rate of tissue/tumor ingrowth and re-occlusion. This tissue ingrowth also makes stent retrieval extremely difficult.

Given these drawbacks, covered stents were developed. Covered SEMSs come in two major varieties: fully covered and partially covered (**Figure 7.5**). They consist of a woven metal alloy frame, commonly Nitinol, and some sort of coating material, often polytetrafluorethylene.⁸ Fully covered SEMSs have no exposed metal, while partially covered SEMSs have a proximal and distal margin of uncovered metal with the goal of minimizing migration. More recently, we have seen the development of the self-expanding plastic stent (SEPS), in which no metal is used.

While the initial self-expanding stents were used to manage malignant disease, their lower complication rates and better patient tolerability made them better equipped for use in benign conditions as well. Today's SEMSs and SEPSs are used for benign esophageal strictures from gastroesophageal reflux disease and caustic ingestion, esophageal fistulas, perforations, and even surgical complications such as staple line leaks from sleeve gastrectomies.⁹

TECHNIQUE

SEMSs and SEPSs can be deployed in two fashions depending on the stent type: Through the scope (TTS) and

non-through the scope. In either delivery system, a guidewire is used to direct the stent into the proper location. Preoperative evaluation is much the same as that for dilatation where a swallow study and upper endoscopy are used to evaluate and characterize the stricture. This includes measurement of stricture length and determination of proximal and distal margins.

The procedure can be performed under sedation, though most endoscopists prefer general anesthesia with the goal of improved patient tolerance and decreased rate of peri-procedural aspiration. Fluoroscopy is used in both techniques. The wire is passed 20 cm beyond the stricture and the proximal and distal extent of the stricture marked. This can be done endoluminally with clips or externally with radiographic markers. Our institution finds externally placed paper clips to be cheap and effective markers. Once the stricture length is determined, the proper stent length is chosen. We generally aim to have the stent in the middle of the stricture or leak and to have least 5 cm extension proximal and distal to the stricture or leak margins.

TTS stents are performed with the endoscope and fluoroscopy, giving the endoscopist both endoluminal and radiographic views of the stent deployment. In this case, a therapeutic scope is required to accommodate both the guidewire and the deployment device. Non-through scope devices are deployed with fluoroscopic viewing only. In this technique, the scope is withdrawn from the patient, and the deployment device with contained stent is passed over the guidewire under fluoroscopic observation. The deployment technique differs for each stent manufacturer, and the user should familiarize him- or herself with the package instruction prior to use.

Most SEMS and SEPS placement can be adjusted if not fully deployed (**Figure 7.6**). Many fully covered stents can usually be pulled back once fully deployed by grasping the retrieval loop at the proximal ring of the stent. Advancement after full deployment is often not possible. Some authors recommend using an endoluminal injection of a contrast mix following deployment to confirm proximal sealing of



Figure 7.6 Stent on deployment device.



Figure 7.7 Deployed stent.

the stent, though this is not routinely performed at our institution ([Figure 7.7](#)).

Outcomes

Outcomes from SEMSs and SEPSs depend on the underlying condition being treated. Esophageal and anastomotic leaks as well as perforations are discussed in more detail in [Chapter 13](#). In regard to stenosis, the data on long-term resolutions are varied. Initial reports suggested success rates as high as 80%. More recent prospective studies have shown those numbers to be a bit exaggerated, with success rates in the 20%–40% range for SEMSs.^{8,10}

Covered SEMSs and SEPSs have helped to correct many of the complications of uncovered stents, mainly stent erosion and tissue ingrowth. Unfortunately the coating of these stents has led to an increase in stent migration. Migration is the most common complication of SEMSs and SEPSs with reported rates around 30% but as high as 80% in some studies.^{9,11} Partially uncovered stents seem to improve these rates with better tissue adhesion from the uncovered portions.

Lower migration rates of uncovered and partially covered SEMSs comes at a price with significantly higher rates of tissue embedment and occlusion, erosion, fistulas, and severe bleeding. Furthermore, retrieving an uncovered stent can be extremely challenging and often requires a technique of deploying a covered stent within the first, leading to necrosis of the ingrowth. Bronchoesophageal and aorto-esophageal fistula along with massive gastrointestinal bleeds, though rare, are potentially life-threatening complications.

The future of esophageal stents may lie within the recent development of biodegradable stents.¹² These stents would have an advantage over standard self-expanding stents with a prolonged time for dilation and absence of need for stent retrieval. Preliminary data are varied with reported success rate up to 50% and complication rates similar to SEMSs and SEPSs.¹² Larger randomized controlled studies are needed to appropriately compare these newer-generation stents.

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Therapeutic upper endoscopy II: Treatment of Barrett esophagus

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INTRODUCTION

Barrett esophagus is defined as the conversion of normal esophageal squamous epithelium to specialized columnar-line epithelium related to symptomatic or asymptomatic gastroesophageal reflux. Patients with Barrett esophagus are at increased risk of developing esophageal adenocarcinoma.^{1,2} This risk is directly related to the grade of dysplasia present: intestinal metaplasia: 4 per 1,000 patients per year; low-grade dysplasia: 7–8 per 1,000 patients per year; and high-grade dysplasia: 146 per 1,000 patients per year.^{1,2} Although controversies exist with regard to screening, surveillance, and surgical management of the disease, the focus of this chapter is endoscopic management.

DIAGNOSIS

Barrett esophagus is diagnosed endoscopically. Although standard white light endoscopy has been the standard in visualizing the “salmon-colored” epithelium of Barrett esophagus, more recent recommendations include the use of high-definition endoscopy.¹ This can readily identify the change in color of squamous epithelium to intestinal metaplasia (**Figure 8.1**). Not uncommonly, it may be difficult to distinguish between normal squamous epithelium and Barrett epithelium. In these cases, narrow-band imaging effectively enhances the distinction between Barrett epithelium and squamous epithelium (**Figure 8.2**).

Visual identification alone is not adequate to diagnose Barrett esophagus—pathologic evaluation from tissue biopsies is necessary. Despite continued controversy regarding the definition of Barrett esophagus, several key components are necessary for pathologic diagnosis. In Europe, the pathologic diagnosis of Barrett esophagus necessitates the

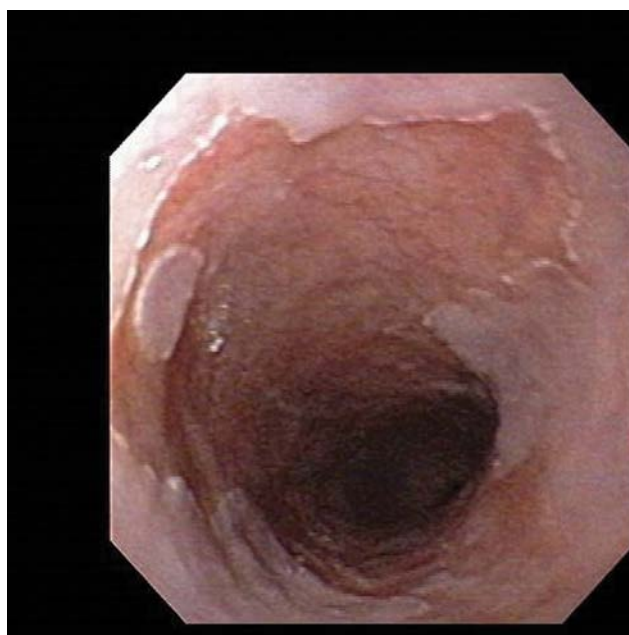


Figure 8.1 High-definition white light image of Barrett esophagus.

presence of glandular mucosa and goblet cells. While in the United States, pathologic diagnosis that requires intestinal metaplasia with periodic acid-Schiff positive staining of goblet cells remains the most widely used method of diagnosis (**Figure 8.3**).

It is important to adequately report the length of the Barrett esophagus segment. Some standardization has been achieved with the introduction of the Prague classification, employing the extent of circumferential length of Barrett metaplasia (C) and the total length of metaplasia (M)

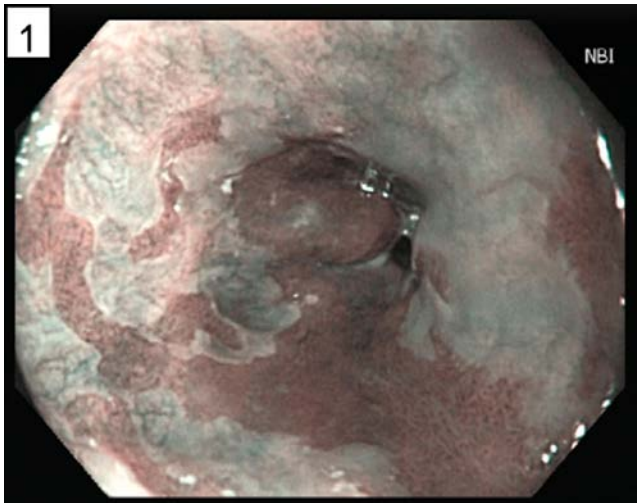


Figure 8.2 Narrow-band imaging of Barrett esophagus.

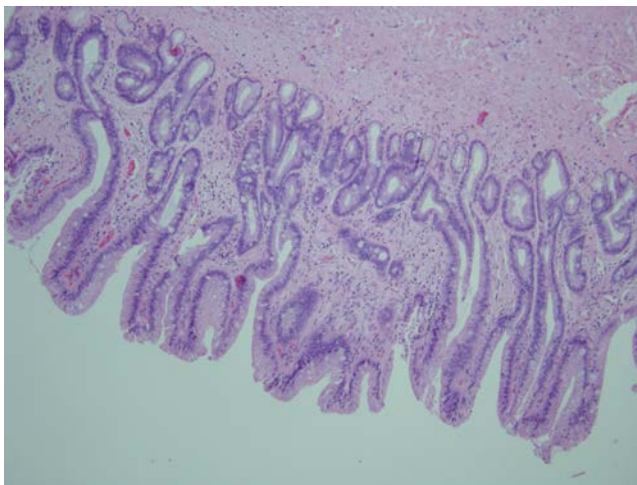


Figure 8.3 Photomicrograph of Barrett metaplasia. Note the columnar-lined epithelium with goblet cells.

of the Barrett esophagus.³ Once length is established, it is important to adequately sample the entire length of Barrett epithelium, otherwise the risk of sampling error increases. Currently, the Seattle protocol calls for obtaining four-quadrant biopsies every 2 cm.⁴ It is very important that “suspicious” areas, namely, nodules or ulcers within segment of Barrett metaplasia, be biopsied thoroughly, as these will have the highest yield of malignancy.

ENDOSCOPIC MANAGEMENT

Rationale for treatment

Until Barrett metaplasia progresses to carcinoma, it is a mucosal disease. Therefore, eradication only requires

removal of the diseased mucosa, not the entire organ. This concept of removing cancer-prone tissue is not new to surgeons. There are numerous examples of premalignant diseases that are treated with “prophylactic” resection prior to the development of malignancy.

With respect to Barrett metaplasia, the value of ablation is dependent on the incidence of progression to invasive carcinoma. Although prevention of esophageal adenocarcinoma is the primary reason to perform ablation, there are other reasons as well. First, ablation may be a cost-effective alternative to observation. Inadomi et al.⁵ have shown that for all grades of dysplasia, ablation is more cost-effective than surveillance. This is particularly true when one considers the costs of esophagectomy.⁶ In a sense, ablation can be considered a method to prevent esophagectomy. Although esophagectomy has a high cure rate for adenocarcinoma in a screened Barrett population,⁷ it does come at a cost in quality of life.⁸ In addition, the presence of Barrett esophagus does affect quality of life, and ablation seems to improve it.⁹ Although it now appears that ablation of Barrett esophagus with high-grade dysplasia is an accepted standard of care,¹⁰ data also support that its use in low-grade dysplasia reduces the progression to adenocarcinoma, and an argument can be made for ablation of nondysplastic Barrett metaplasia.¹¹ This argument centers on the facts that the morphologic evaluation of dysplasia is fraught with error; some studies show a substantial progression rate of low-grade dysplasia to cancer; post-ablation neosquamous epithelium reveals no molecular abnormalities and is biologically stable; and no other method reliably reduces cancer risk, is durable, and eliminates the need for surveillance.

Endoscopic ablation techniques

Once the decision is made to proceed with endoscopic ablation, several techniques are available.

Photodynamic therapy

Photodynamic therapy (PDT) involves injecting light sensitizing drugs into the esophagus (such as porfimer sodium) and exposing the injected portion to a specific wavelength of light to promote cell death. However, the demonstrated effectiveness is not as high as initially hoped, and the complication rates after treatment may outweigh the benefits. Although PDT works to ablate the segment of Barrett esophagus, buried glands may be unaffected and the dysplasia may persist underneath a layer of normal-appearing squamous epithelium. A randomized trial comparing PDT and omeprazole to omeprazole only demonstrated 13% progression to adenocarcinoma in the PDT group compared to 28% progression with the proton pump inhibitor group, percentages that are still quite high.¹² In patients with long-segment Barrett esophagus, stricture rates after ablative

therapy may be as high as 40%,¹³ contributing to further loss of popularity of this modality.

Multipolar electrocoagulation

Multipolar electrocoagulation (MPEC) uses an endoscopic multipolar electrical probe to treat the areas of metaplasia. Complete eradication of Barrett esophagus can be as high as 88% in 3 months post-ablation¹⁴; however, success rates are operator dependent, and all areas must be treated equally. Dysphagia was the most common side effect in another series of patients.¹⁵

Argon plasma coagulation

Argon plasma coagulation (APC) produces a flow of ionized argon plasma, generating a high-frequency monopolar current. The 3-month eradication rates are in the high 80% range,¹⁴ with lower rates of stricture formation and bleeding compared to PDT. Odynophagia rates were more than 10% with this modality.¹⁵

Radiofrequency ablation

Radiofrequency ablation (RFA) employs bipolar electrical energy to the mucosal surfaces at frequencies at the radio level. The most widely used and best studied of these devices is the BARRx system^{16,17} (Figure 8.4).

The general steps of ablation is to first determine the size of the area of Barrett epithelium to be treated. If it is a large area, the Halo-360 device is used; if it is a small area, the Halo-90 device is chosen. When using the Halo-360 device, after the length of Barrett epithelium to be ablated is determined, a sizing catheter is passed into the esophagus to the

level to be ablated. The balloon is inflated and the size of the ablating catheter determined. The ablating catheter is passed to the level of ablation and the endoscope passed alongside for visualization. The ablating balloon is inflated to create contact with the esophageal mucosa and suction applied to the esophageal lumen. The applied energy is 10 joules per second. The balloon is deflated. The coagulum is removed from the ablated segment of the esophagus and the process repeated. This effectively ablates to the submucosal level, and within several weeks to months, a new squamous epithelium arises at the site (Figure 8.5).¹⁸ Alternatively, if only a relatively small segment of Barrett epithelium is to be treated, the Halo-90 device can be used. This device is attached to the end of a standard endoscope to which it is oriented at the 12 o'clock position of the scope and visualized at the top of the monitor. After identifying the segment to be treated, the scope is deflected up to the segment and energy applied. Using the device, the coagulum is removed and the energy applied once again. This process can be repeated until all of the area of planned treatment is completed.

A one-time RFA is 70% effective in eliminating Barrett metaplasia. Thus, follow-up sessions are required, usually at 3- and 12-month intervals.¹⁹ There is superiority of endoscopic RFA in reduction of carcinoma progression in non-dysplastic metaplasia, low-grade dysplasia, and high-grade dysplasia. Endoscopic RFA can eliminate Barrett esophagus with high-grade dysplasia and reduce the risk of esophageal adenocarcinoma.²⁰ In a study following patients at 3 years, complete eradication of intestinal metaplasia was still present in 91% of patients, 96% of patients with high-grade dysplasia. However, patients with segments shorter than 3 cm in length of Barrett esophagus are the optimal population.²¹ However, even after complete eradication, up to 30% of patients will still have recurrence of Barrett metaplasia at some time post-treatment follow-up.

Cryoablation

Cryoablation involves directed spray of liquid nitrogen at -196°C onto the affected segment.^{22,23} After the segment of Barrett epithelium to be treated is identified, a catheter is passed through the scope into the esophageal lumen. Under direct visualization, the liquid nitrogen is sprayed onto the epithelium. Complete eradication of intestinal metaplasia occurs in 68%–97% of patients,^{24,25} complete eradication of intestinal metaplasia occurs in 57% of patients,²⁰ and eradication of intramucosal adenocarcinoma occurs in 80% of patients.²³

Endoscopic mucosal resection

Endoscopic mucosal resection (EMR) is most useful in nodular Barrett esophagus, as the risk of high-grade dysplasia or malignancy is greatest in these areas,³ or when a short segment of dysplasia is present. EMR can be used for



Figure 8.4 The BARRx generator with Halo-360 ablation catheter and Halo-90 endoscope ablation attachment.

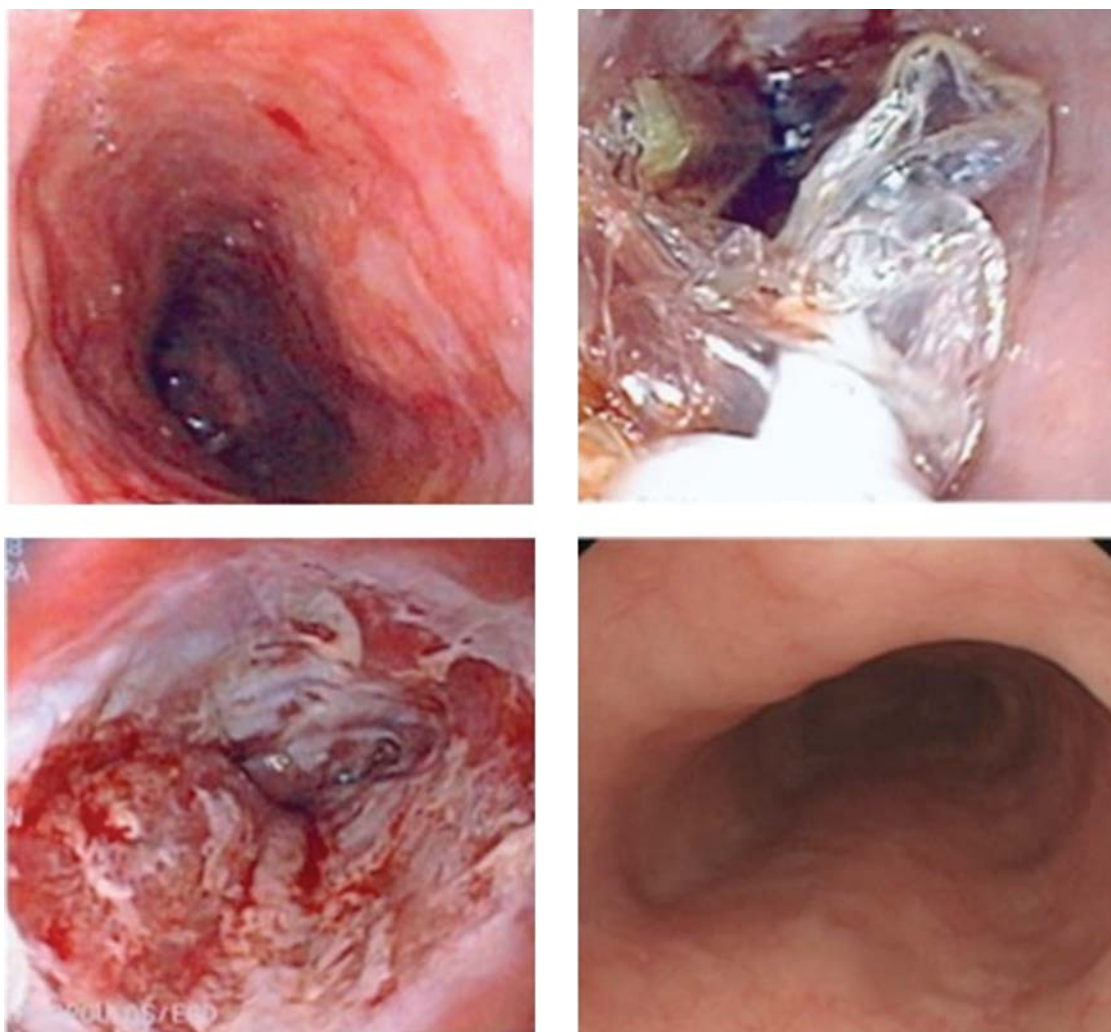


Figure 8.5 Clockwise from the upper left image: Sequence of identification of Barrett esophagus, ablation with the Halo-360 device, immediate post-ablation coagulum and ulceration, and final replacement of Barrett epithelium with normal squamous epithelium.

Tis and T1a esophageal adenocarcinoma as long as submucosa is not involved, as the risk of lymph node involvement is low. EMR can be used in combination with RFA to resect both nodular Barrett high-grade dysplasia and “flat” Barrett metaplasia.²⁶

Techniques of EMR are covered in greater detail in [Chapter 10](#).

CONCLUSION

Endoscopy is essential in the diagnosis of Barrett esophagus. RFA has become the standard of care for Barrett esophagus with high-grade dysplasia and should be considered in patients with low-grade dysplasia or other high-risk features. EMR should be used in patients with nodules with or without additional ablation of the areas of “flat” Barrett metaplasia.

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Therapeutic upper endoscopy III: Treatment of gastroesophageal reflux

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INTRODUCTION

Gastroesophageal reflux disease (GERD) is a complex disorder resulting from multiple factors including abnormal lower esophageal sphincter function, acid production, and/or alteration of the diaphragmatic hiatus and angle of His.¹ These abnormalities most commonly result in heartburn, dysphagia, and regurgitation. Atypical symptoms such as chronic cough, hoarseness, laryngitis, and noncardiac chest pain may also be encountered.² Symptomatic GERD has been reported in 30%–40% of adults and negatively impacts sleep, productivity, and overall quality of life.³ Left untreated, it can progress to erosive esophagitis, stricture, Barrett esophagus, esophageal adenocarcinoma, as well as other pulmonary and laryngeal conditions.⁴

The initial diagnosis of GERD is made based on patient symptoms and response to lifestyle modifications and proton pump inhibitors (PPIs). A significant proportion of patients who cannot tolerate PPIs or remain symptomatic despite maximal medical therapy are confirmed to have gastroesophageal reflux via esophagogastroduodenoscopy (EGD) and pH testing. These patients should be considered for endoscopic or surgical treatment. Laparoscopic Nissen fundoplication remains the gold standard for the treatment of GERD with 80%–90% of patients no longer requiring PPIs 10 or more years after surgery.^{5,6} However, many suitable patients avoid or are not offered antireflux surgery due to concerns about the risk of perioperative complications and long-term side effects including dysphagia, bloating, and flatulence. This treatment gap between medical and surgical treatment has driven the evolution of endoscopic GERD therapies that may adequately control symptoms with fewer side effects.

Endoluminal therapies for GERD have focused on improving the lower esophageal sphincter (LES) function

through the delivery of radiofrequency energy (Stretta) or endoscopic suturing/stapling devices (EsophyX, MUSE) that restore the structure of a competent LES.⁷ This chapter discusses the indications and outcomes of currently available endoscopic reflux therapies:

1. Radiofrequency ablation (Stretta, Mederi Therapeutics, Greenwich, Connecticut)
2. Transoral fundoplication (EsophyX, EndoGastric Solutions, Redmond, Washington)
3. Endoscopic stapling (Medigus Ultrasonic Surgical Endostapler, Medigus, Tel Aviv, Israel)

TECHNIQUES

Radiofrequency ablation (Stretta)

TECHNIQUE AND INDICATIONS

Stretta was initially approved by the U.S. Food and Drug Administration (FDA) in 2000 and received updated clearance for a new radiofrequency generator in 2011. This device delivers low-power (5 Watt) radiofrequency energy to the LES while protecting the esophageal mucosa with temperature-controlled irrigation. Stretta can be performed as an outpatient procedure with conscious sedation and begins with standard endoscopy and measurement of the gastroesophageal junction (GEJ). A guidewire is then placed through the endoscope and exchanged for the Stretta catheter. The catheter is positioned 2 cm proximal to the GEJ and four nickel-titanium electrodes are deployed (**Figure 9.1**). Radiofrequency energy is then delivered to the esophageal musculature via these needle electrodes with continuous power adjustment based on tissue impedance and mucosal

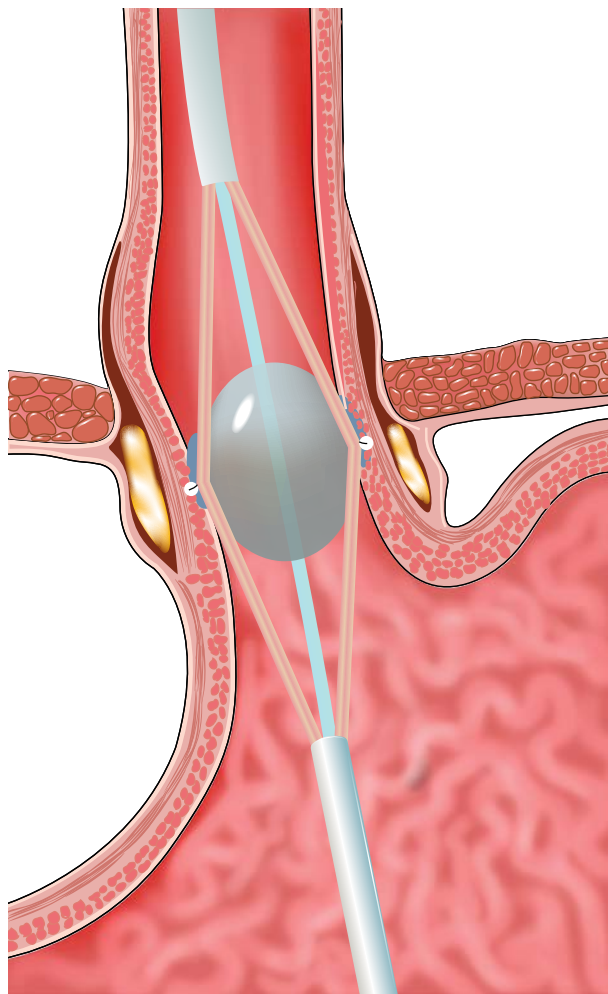


Figure 9.1 Stretta radiofrequency ablation. The Stretta catheter, once positioned and inflated, deploys four nickel-titanium electrodes into the esophageal muscle. It is activated twice at eight different treatment levels to complete the procedure.

temperature. The device is then rotated 45° and fired again to complete a treatment level consisting of eight treatment sites. This is then repeated after moving distally 0.5 cm and continued for a total of eight treatment levels (four above and four below the Z-line). Two additional gastric cardia treatment levels are created to complete the procedure.

The exact mechanism of reflux control following radiofrequency ablation of the LES is unknown and likely multifactorial. Remodeling the musculature of the GEJ and gastric cardia as well as ablation of vagal nerve endings are thought to restore the natural barrier function of the LES.⁸ Symptom improvement may also result from decreased esophageal acid sensitivity and reduced frequency in transient LES relaxations.⁹ Currently, Stretta is indicated for use in adults with chronic gastroesophageal reflux for 6 months that is at least partially responsive to PPI therapy. Normal esophageal peristalsis and pathologic reflux should be confirmed with manometry and pH or impedance monitoring prior to any

intervention. Patients with severe esophagitis, long-segment Barrett esophagus, known collagen vascular disease, or a hiatal hernia larger than 2 cm should not undergo Stretta.

EVIDENCE

The first randomized, sham-controlled trial was published in 2003 and demonstrated significantly improved symptom scores and quality of life at 12 months.¹⁰ However, there was no difference in PPI usage or esophageal acid exposure at follow-up. Coron et al. found similar results in a randomized double-blind, sham-controlled multicenter study of 65 patients. At 6 months, the active treatment group had significantly improved symptoms and quality of life.¹¹ Another prospective, randomized, double-blind, sham-controlled crossover study was published by Arts et al. and again demonstrated improved GERD symptoms thought to be a result of decreased GEJ compliance resulting in decreased acid exposure at 3 months.¹²

A meta-analysis of randomized controlled trials and cohort studies reported on 18 studies over a 10-year span including 1,441 patients.¹³ Heartburn scores significantly improved as did quality of life as measured by the GERD-Health Related Quality of Life (GERD-HRQL) and Quality of Life in Reflux and Dyspepsia (QOLRAD) questionnaires. DeMeester scores significantly decreased from 44.4 to 28.5. Complications such as gastroparesis and erosive esophagitis were rare. Major complications occurred in less than 0.24% of patients.

Long-term follow-up has been published by Noar et al. following 217 patients who were treated with Stretta for medically refractory reflux.¹⁴ At 10 years, GERD-HRQL scores had normalized in 72% of patients. The majority (64%) reduced their PPI use by 50%, and 89 patients (41%) stopped their PPI use completely. Preexisting Barrett metaplasia regressed in 85% of patients, and there were no cases of esophageal cancer.

Transoral fundoplication (EsophyX)

TECHNIQUE AND INDICATIONS

Transoral fundoplication using the EsophyX device was introduced as method to create a gastroesophageal plication that would restore the valve function of the angle of His at the GEJ. Transoral fundoplication (TF) was approved by the FDA in 2007 to be performed under general anesthesia. The patient is placed in the left lateral position, and EGD is performed after which the EsophyX device is placed over the scope and manipulated by a second physician. Copious lubrication is required to safely pass the cricopharyngeal constriction, and dilation with a 56 French dilator prior to device insertion facilitates this process. Following device insertion, the GEJ is viewed in retroflexion, and the gastric fundus is drawn into the device tip (Figure 9.2). Between 12 and 20 “H”-shaped polypropylene fasteners are then deployed to create a 200°–310° plication.¹⁵

The first iteration of the procedure, Transoral Incisionless Fundoplication (TIF) 1.0, created a gastro-gastric plication at the level of the squamocolumnar junction. The

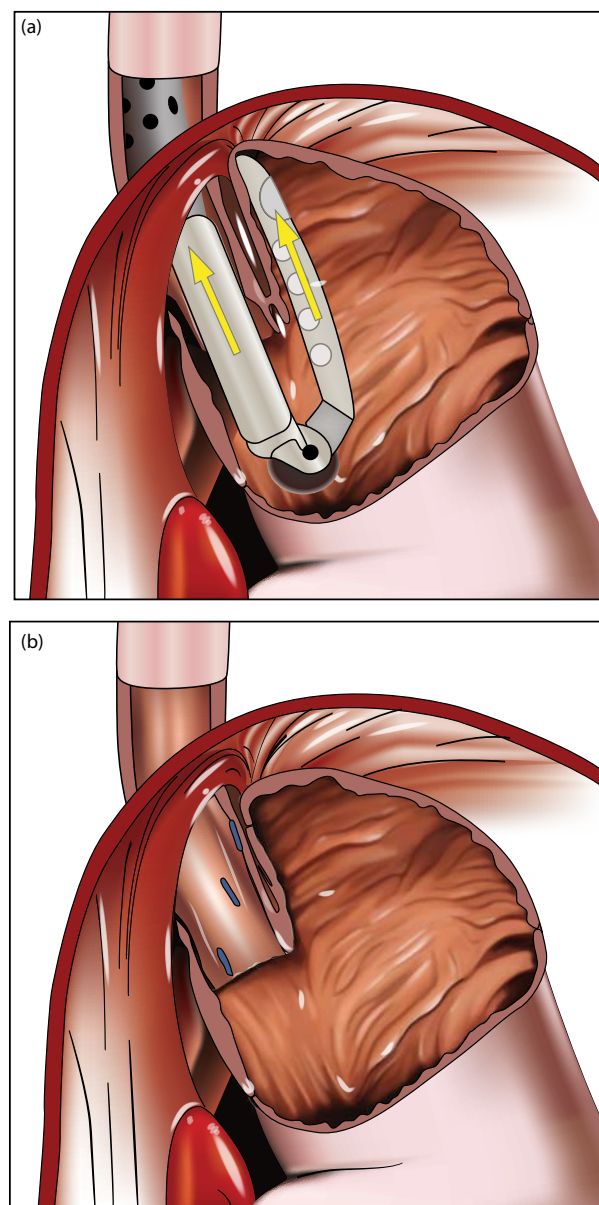


Figure 9.2 Esophyx Transoral Fundoplication. (a) Appropriate placement of TIF 2.0 device with fasteners firing 1–3 cm proximal to the gastroesophageal junction. (b) Completed fundoplication.

second-generation procedure, TIF 2.0, places fasteners 1–3 cm proximal to the GEJ creating a gastroesophageal plication that is thought to create a stronger valve resulting in durable increases in resting LES pressure.¹⁶ Currently, TIF 2.0 is indicated for use in adults with chronic gastroesophageal reflux and/or regurgitation for 6 months that is at least partially responsive to PPI therapy. Patients with severe esophagitis, long segment Barrett esophagus, motility disorders, prior esophageal myotomy, esophageal varices, esophageal stricture, and hiatal hernia greater than 2 cm or a connective tissue disorder should not undergo TF.

EVIDENCE

Cadière et al. published the first prospective clinical trial in 2008 with 1 year of follow-up on 19 patients. At 12 months, 63% had normal esophageal acid exposure and 82% did not require daily PPI therapy. Fifty-three percent of patients experienced at least 50% improvement in their GERD-HRQL.¹⁷ The 2-year follow-up data were equally promising: 64% of patients had at least a 50% improvement in their GERD-HRQL scores, and 71% did not require PPI therapy.¹⁸ The first multicenter study of 84 patients with 12 months of follow-up demonstrated cessation of PPI use in 81% of patients, and 37% had normal esophageal acid exposure. Patients with pre-procedure Hill grade I GEJ valves had the best outcome with 86% discontinuing PPIs and 48% demonstrating normal esophageal acid exposure. Three major complications occurred including two esophageal perforations during device insertion and one case of bleeding requiring blood transfusion.¹⁹ None of the adverse effects of laparoscopic fundoplication (e.g., bloating, dysphagia, and flatulence) were reported.

The first published case series in the United States consisted of a 10-month follow-up of 26 patients. Fifty-three percent of patients had either discontinued PPIs or reduced their dose by at least 50%, and a significant improvement in GERD-HRQL score was also seen (10 from 22, $p = 0.0007$).²⁰ Two hemorrhages requiring intervention were reported. A meta-analysis of 15 cohort studies including over 550 procedures demonstrated improved GERD-HRQL scores after TF with 72% of patients being satisfied and 67% of patients ceasing PPI therapy at a mean follow-up interval of 8 months. The major complication rate was 3.2% with postoperative bleeding being the most common. Overall, 8.1% of patients experienced a relapse of reflux symptoms and underwent a laparoscopic fundoplication.²¹

Recently, two randomized controlled trials have been published. The first compared TF in 39 patients to maximal PPI dosing in 21 patients. After 6 months, TF patients experienced significantly better relief of extra-esophageal symptoms (62% versus 5%, $p = 0.009$) and resolution of bothersome regurgitation (97% versus 50%, $p = 0.006$). Esophageal acid exposure was similar in both groups (54% versus 52%, $p = 0.91$); however 90% of TF patients ceased PPI therapy and 90% resolved preoperative esophagitis compared to 38% of medically managed patients ($p = 0.18$).²² A second study randomized 87 patients to undergo TF plus 6 months of placebo compared to 42 patients who underwent a sham-procedure plus daily omeprazole. Both groups had improved GERD-HRQL scores at 6 months, but TF eliminated regurgitation in a larger proportion of patients (67%) than medical acid suppression (45%, $p = 0.23$). Esophageal acid exposure improved after TF (6.3% from 9.3%, $p < 0.001$) but not after sham surgery (8.6% versus 8.9%), and after 12 months, the majority of medically managed patients (71%) elected to proceed with TF.²³

Long-term follow-up has been reported at 3 and 6 years in two studies. Muls et al. followed 79 patients treated

with TF in a multicenter study, 66 of which had 3 years of follow-up. Twelve (18%) went on to surgery for refractory symptoms, but the remaining 54 patients demonstrated maintenance of low GERD-HRQL scores, and 61% remained free from daily PPI therapy at 3 years. Six-year follow-up of 50 patients was published by Testoni et al. who reported that 52% of patients had stopped PPIs (84% had stopped or halved or their PPIs), although DeMeester scores remained abnormal in many patients. Just 14% went on to laparoscopic fundoplication for treatment failure. Predictors of success in their patients were pre-procedure Hill grade I–II, no hiatal hernia or a hiatal hernia ≤ 2 cm, normal esophageal motility, and a greater number of fasteners deployed.²⁴

Endoscopic fundoplication (MUSE)

TECHNIQUE AND INDICATIONS

The Medigus Ultrasonic Surgical Endostapler (MUSE) combines a flexible gastroscope with a stapler and ultrasound to create a 180° anterior fundoplication (**Figure 9.3**). The procedure is performed under general anesthesia and can be performed by a single operator. Ultrasound guidance measures the tissue thickness of the opposed tissue following alignment of the gastric fundus with a location 1–3 cm above the GEJ. Once aligned, five staples are deployed to create a gastroesophageal plication. The device is rotated 90° and the procedure is repeated twice to create a 180° plication. This procedure received FDA approval in 2012 following preclinical trials and a multicenter clinical trial.^{25,26}

Strict indications have not been determined due to a lack of data, but MUSE has been studied in patients who have more than 1 year of GERD (confirmed by pH study) that is at least partially responsive to PPIs. Patients with a

BMI > 35 kg/m², severe esophagitis, complicated GERD, long-segment Barrett esophagus, or a hiatal hernia greater than 3 cm have not been included.²⁷

EVIDENCE

The initial clinical trial compared 11 patients undergoing MUSE to 16 undergoing laparoscopic fundoplication. MUSE required 89 minutes to perform compared to 47 minutes for fundoplication ($p < 0.05$) and the length of hospital stay was significantly longer (3 days versus 1.2 days, $p < 0.05$). After 6 months, GERD-HRQL scores had significantly improved in both groups, and PPI use remained low (27.3% after MUSE versus 6.3% after laparoscopic fundoplication, $p = 0.131$). One esophageal perforation was reported and successfully treated with endoscopic stenting following MUSE. Due to the trend toward higher postoperative PPI use, longer operative time, and complication rate, the authors concluded that MUSE is currently inferior to laparoscopic fundoplication but may be valuable in select patients.²⁶

A prospective, multicenter cohort study of 69 patients recently reported their 6-month findings. Of 66 patients, 73% improved their GERD-HRQL score by greater than 50%, and 65% no longer required daily PPI therapy. Esophageal acid exposure also significantly decreased but did not normalize. The most common adverse events were chest pain and sore throat, although one patient developed an empyema that required tube thoracostomy, and another patient required endoscopic intervention for hemorrhage. Two patients went on to laparoscopic fundoplication for refractory symptoms, and this was done without additional difficulty. There were no reports of significant dysphagia, bloating, or inability to belch in contrast to laparoscopic fundoplication.²⁷

CONCLUSIONS

GERD is a common disease that can be quite debilitating. All patients with classic symptoms should undergo a trial of medical therapy. Patients who experience some benefit but continue to have symptoms following 6 months after PPI therapy should be considered for procedural reflux therapy. Currently, endoluminal treatments appear most beneficial in patients with symptoms that are at least partially responsive to PPI therapy and who have minimal anatomic changes at the gastroesophageal junction (i.e., hiatal hernia less than 2 cm) and normal esophageal motility. These procedures may be particularly appealing to patients with concerns about the side effects of medical and surgical therapies.

Radiofrequency energy delivery to the LES by Stretta is the most thoroughly studied endoluminal treatment and has demonstrated durable improvements in symptoms with PPI reduction up to 10 years after the procedure in appropriately selected patients. Three- and 6-year data are available for TF by EsophyX and demonstrate reductions in PPI use and improved symptom scores, but long-term effectiveness remains unknown. Data are even more sparse

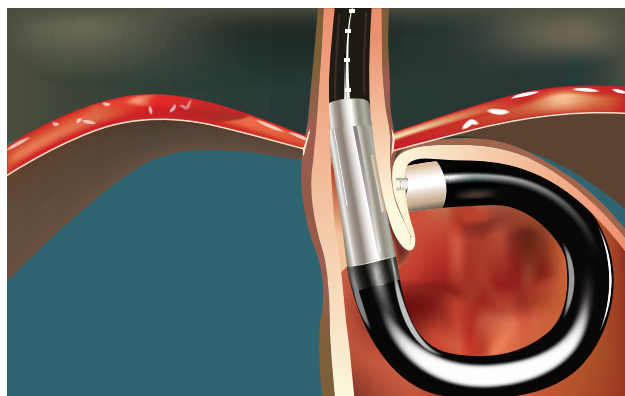


Figure 9.3 Medigus Ultrasonic Surgical Endostapler. MUSE device utilizing ultrasound to align gastric tissue and esophagus 1–3 cm proximal to the gastroesophageal junction. This is done via a single endoscope (in contrast to EsophyX, which requires the device and a second endoscope for visualization).

for MUSE, although short-term studies are promising. Further studies are required to identify the optimal patient populations and establish the long-term efficacy of these therapies.

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Endoscopic mucosal resection, endoscopic submucosal dissection, and endoscopic full-thickness resection in the upper gastrointestinal tract

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ROLE FOR ENDOSCOPIC RESECTION IN THE UPPER GASTROINTESTINAL TRACT

Endoscopic resection techniques have evolved since the 1980s for resection of mucosal-based lesions in the upper gastrointestinal (GI) tract. Endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD) enable endoscopic resection of lesions confined to the mucosa and submucosa. The plane for resection for both techniques lies between the submucosa and the muscularis propria. Endoscopic full-thickness resection (EFTR) enables a full-thickness resection of the GI tract. For malignant lesions, appropriate application of endoscopic resection is contingent on lesions having minimal risk of lymphatic invasion, equivalent or less than the risk of mortality associated with surgical resection with lymphadenectomy. There are no absolute indications of endoscopic resection. Surgical resection with lymphadenectomy is presented as a treatment option for all malignant lesions in North American guidelines, as there will always be a potential risk for lymphatic spread. When selecting appropriate patients, one must weigh this risk with the risk of morbidity/mortality associated with surgical resection versus the risk of leaving residual malignant tissue with endoscopic resection.

For esophageal adenocarcinoma and squamous cell carcinoma, appropriate lesions for consideration of endoscopic resection have been outlined by the National Comprehensive Cancer Network (NCCN).¹ Candidate lesions are mucosal based, including Tis and T1a lesions, in the absence of high-risk features such as lymphovascular invasion or poor differentiation grade. Appropriate lesions must be adequately controlled by endoscopic resection, outlined as less than

2 cm in diameter. This size criteria is supported by analysis of superficial esophageal cancers in the National Cancer Database, showing the risk of lymphatic invasion diminished to 0.5% in low-grade lesions, less than 2 cm in diameter, compared to a 5% risk in all T1a lesions.² The NCCN guidelines also recommend that residual intestinal metaplasia should be eradicated using ablative techniques such as radiofrequency ablation or photodynamic therapy.

Appropriate gastric adenocarcinoma lesions for endoscopic resection have similar criteria as outlined for esophageal cancer. Candidate lesions for endoscopic resection are mucosal-based Tis and T1a lesions, well or moderately differentiated, with absence of lymphovascular invasion, and less than 2 cm in diameter. Evidence for endoscopic resection of gastric lesions is largely based out of Asia, where higher rates of screening upper endoscopy are performed, and higher rates of early gastric cancers are detected. The adoption of endoscopic resection for early gastric cancer has been based on landmark studies from Japan, evaluating the risk of lymphatic invasion based on pathologic criteria. Although the incidence of lymphatic invasion for intramucosal cancer is 3%,³ a select pathologic subgroup has been identified with virtually no risk of lymph node metastases in retrospective pathologic studies. These patients had differentiated mucosal gastric cancer, less than 3 cm in diameter, without lymphovascular invasion or ulceration.⁴

For submucosal tumors, such as GI stromal tumors, endoscopic full-thickness resection may be used as an alternative to laparoscopic resection. Full-thickness resection is required, as these lesions arise from the muscular layer. Lymphadenectomy is typically not indicated for GI stromal tumors given the negligible risk for lymphatic invasion.

ENDOSCOPIC MUCOSAL RESECTION

EMR was developed as an adaptation of snare polypectomy for pedunculated lesions. EMR technology allows resection of flat, mucosal-based lesions that do not have a pedunculated stalk. The tenets of EMR are to separate the mucosa from the muscularis propria and facilitate grasping of these lesions to allow for *en bloc* resection. Without these adjunct techniques, simple snare excision would jeopardize *en bloc* resection and cut into the margins of the mucosal-based lesion.

The first adjunct technique is to separate the mucosa and muscularis propria. This is achieved by injection of saline or a colloid solution below the mucosal layer. This is a widely practiced technique to facilitate polypectomy.

The second adjunct technique is to lift the mucosal-based lesion to allow complete *en bloc* resection. These adjuncts have evolved over time with advances in endoscopic devices. The first described method in this evolution of techniques was the “strip biopsy.” First described in 1984, this technique requires a double-channel gastroscope, allowing the lesion to be lifted using an endoscopic grasping forceps and subsequently removed by snare excision (Figure 10.1).

The development of cap-fitted endoscopes enabled suction to replace the grasping forceps as a method to lift mucosal-based lesions. EMR with cap-fitted endoscopes was described in 1992. A snare is widely deployed around the target lesion. The target mucosal lesion is lifted with suction into the cap. The snare then excises the mucosa and submucosa (Figure 10.2).

The development of variceal band ligation technology has been applied to EMR as a means to capture the targeted lesion as a “polyp.” This technique was first described in 2006 and is superior to the previously discussed techniques as it enables direct visualization as the snare cuts across the base of the targeted lesion. The variceal band ligator comes preassembled with a cap. The cap and ligator are attached to

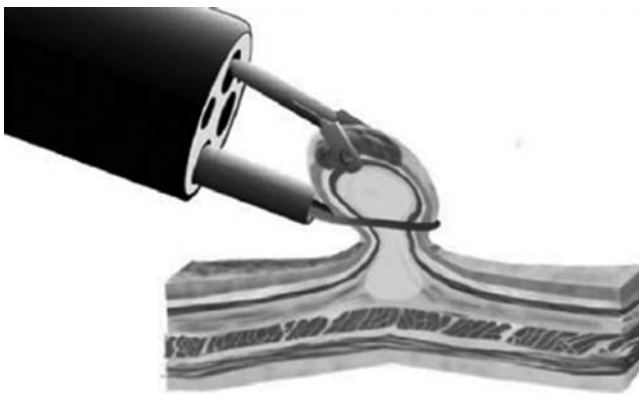


Figure 10.1 Strip biopsy technique. (From Gotoda T et al. *J Gastroenterol* 2006;41:929–42.)

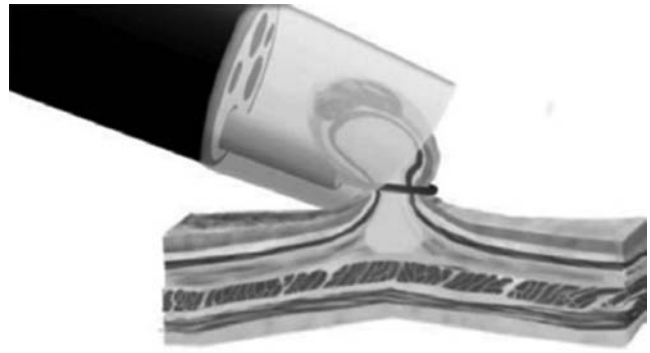


Figure 10.2 EMR with cap-fitted endoscopy. (From Gotoda T et al. *J Gastroenterol* 2006;41:929–42.)

the end of the gastroscope, and the deployment handle is fed through the biopsy channel. The targeted lesion is suctioned into the cap, and a band is deployed at its base to capture the desired lesion as a “polyp.” This “polyp” is then resected using a snare (Figure 10.3).

When using cap-fitted endoscopy as a means to perform EMR, mucosal tissue can only be drawn into the cap if there is a clear plane between the mucosa and muscular layer. Should there be invasion into the muscularis propria or significant submucosal scarring from previous endoscopic resection, the mucosa does not lift readily into the cap. In the case of EMR with band ligation, the mucosa will not lift sufficiently to deploy a band.

One of the main limitations with EMR is the size limitations associated with this technique. As these techniques use a single vector of lifting the mucosa, either through a grasping forceps or suction into a cap, only small lesions can be resected in an *en bloc* fashion. The upper ceiling for lesions amenable to *en bloc* EMR is 2 cm. As interest expands to perform endoscopic resection on larger lesions, and in particular lesions within the stomach, endoscopic submucosal dissection has been developed.



Figure 10.3 EMR with assistance of the variceal band ligator. (From Gotoda T et al. *J Gastroenterol* 2006;41:929–42.)

ENDOSCOPIC SUBMUCOSAL DISSECTION

ESD allows for direct visualization of the submucosal and lateral dissection margins. Compared to EMR, this technique allows for more direct control of dissection margins. EMR provides a single vector of tension to separate the mucosa from the muscular layer and resect along this junction. ESD provides direct visualization of this dissection plane, allowing for greater control of the tissue to be resected.

ESD consists of three central components. Similar to EMR, ESD utilizes infiltration of saline or colloid solution into the submucosal layer to facilitate dissection. Second, the lateral dissection margin is marked out with the needle knife as a series of superficial cautery marks. These marks act as a road map for dissection, as mucosa tends to contract after cutting. This distortion can jeopardize the lateral margins if overlooked. The superficial cautery marks are connected using an insulated tip needle knife. The insulated tip is inserted between the plane of the mucosa and muscular layer, preventing perforation of the muscular layer. The cutting blade sits above the insulated tip, dividing the mucosal layer between the dots. The final step in ESD is the dissection of the mucosa from the muscularis propria using the needle knife. At this stage of the dissection, submucosal vessels may be encountered, which need to be meticulously dissected and cauterized to optimize visualization (Figure 10.4).

ESD is performed with a cap-based endoscope. The cap facilitates an endoscopic view, where tissue is pushed away from the end-viewing camera and the needle knife. This provides optimal visualization for dissection. The cap can also be used to provide upward traction of the mucosal flap, facilitating identification of the plane of connective tissue separating mucosal and muscular layers (Figure 10.5).

ENDOSCOPIC MUCOSAL RESECTION VERSUS ENDOSCOPIC SUBMUCOSAL DISSECTION

EMR is limited by size criteria of the targeted lesion. Only a 2 cm diameter of mucosa can be captured by the cap-based

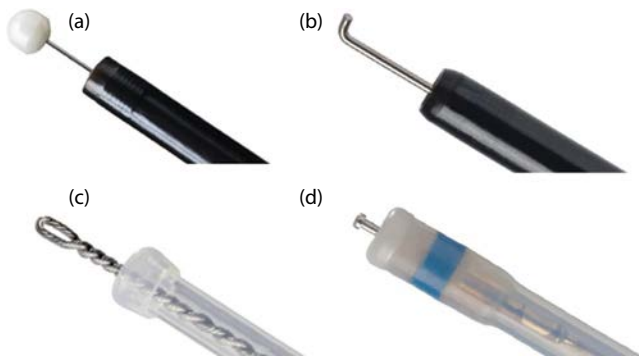


Figure 10.4 Needle knives used for ESD. (a) Insulation-tipped knife. (b) Hook knife. (c) Flex knife. (d) Dual knife. (Image Courtesy of Olympus America Inc.)

suction techniques. Lesions larger than 2 cm are at risk of a piecemeal excision, increasing the risk of local recurrence. ESD technology enables a customized resection and is not limited by size criteria. Comparisons of EMR versus ESD have shown superior rates of *en bloc* resection. This has been demonstrated in meta-analysis comparing the two techniques in both esophageal and gastric resections. Rates of *en bloc* resection were 91.7% versus 52.1% (odds ratio [OR] 8.43)⁶ for gastric resections and 97.1% versus 49.3% (OR 52.76)⁷ for esophageal resections for ESD and EMR, respectively. Some studies have demonstrated equivalent rates of *en bloc* resection for smaller lesions less than 1.5 cm⁸ and 0.7 cm,⁹ but this has been contested in the previously described meta-analyses.⁶

However, the advantages of ESD come at the price of a significantly longer procedure time and a higher rate of complications. In a review by the American Society of Gastroenterology,¹⁰ the duration of procedure for ESD is 84.0 ± 54.6 minutes compared to 25.8 ± 25.9 minutes for EMR. The rate of perforation for ESD is 4%–10% compared to 0.3%–0.5% for EMR. This is a reflection of the significantly steeper learning curve associated with ESD. Performing ESD requires meticulous dissection with the unstable platform of the flexible endoscope. This requires patience and advanced skill. It is estimated that performance of 30 ESDs is required to achieve basic competence, and performance of 80 ESDs is required for proficiency with difficult lesions.^{11,12} Given this steep learning curve, there has been slow adoption of this technique at centers with low rates of early gastric cancers, which are the starting point for developing skills with ESD.

ENDOSCOPIC FULL-THICKNESS RESECTION

EFTR enables full-thickness resection of the GI tract. Full-thickness resection can be performed by purely endoscopic techniques or as a hybrid technique with laparoscopy. Currently, this technology is directed toward small submucosal tumors, such as GI stromal tumors. These tumors have a negligible risk of lymphatic invasion and are ideally suited to local excision. Mucosal-based lesions cannot be excised with most full-thickness resection techniques, given the risk of malignant seeding of the peritoneal cavity. There is developing interest in using full-thickness resection techniques for mucosal-based lesions not amenable to EMR or ESD. In order to prevent peritoneal seeding, hybrid techniques have been developed to completely separate the mucosal dissection from the peritoneal cavity, which are described later in this chapter.

ENDOSCOPIC FULL-THICKNESS RESECTION (PURE ENDOSCOPIC APPROACH)

EFTR as a term is reserved for full-thickness endoscopic resection solely using an endoscope. The technical difficulty with EFTR lies in the closure technique of the resection line. Several current case series describe the use of an

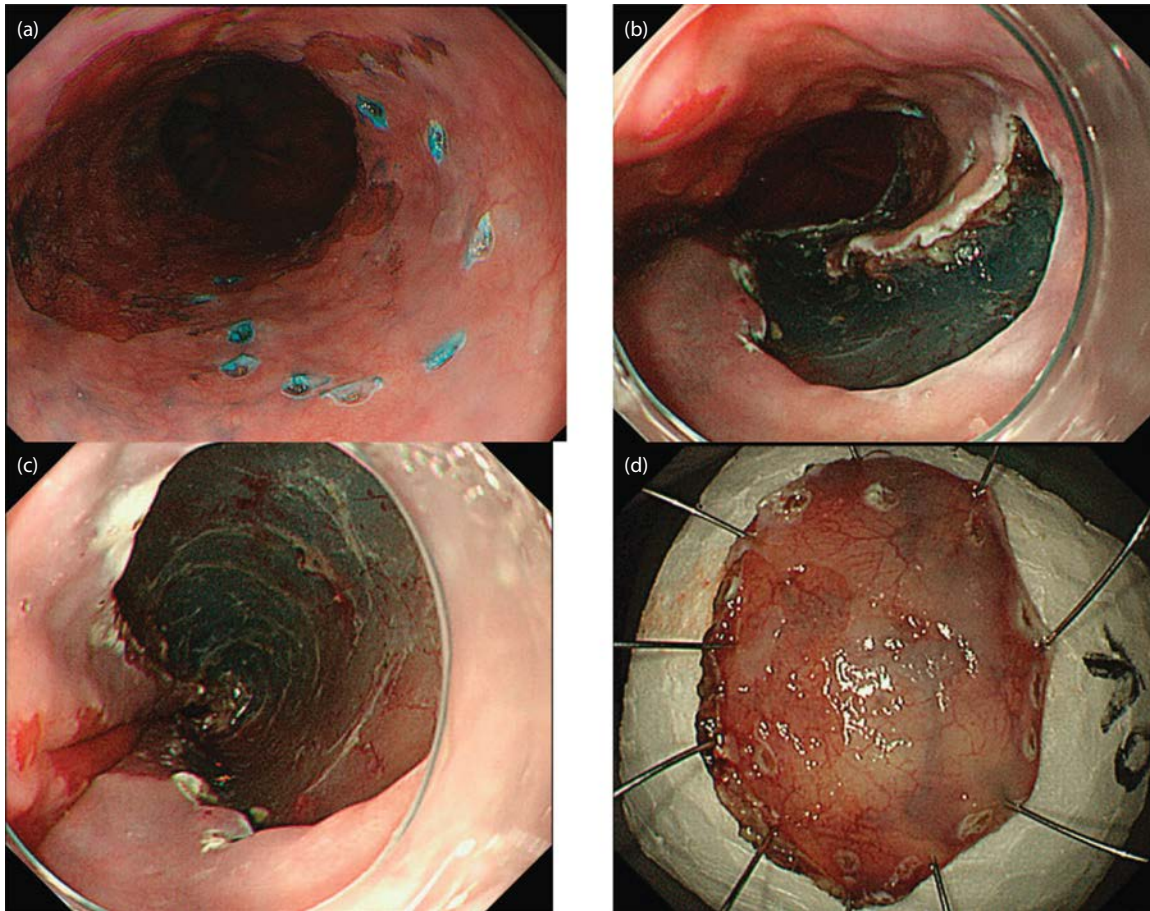


Figure 10.5 Early esophageal adenocarcinoma ESD. (a) Marking. (b) Partial circumferential incision. (c) ESD mucosal defect. (d) Resected specimen. (From Bhatt A et al. *Am J Gastroenterol* 2015;110[6]:784–91.⁵)

Over-the-Scope Closure Device (OTSC, Ovesco Endoscopy, Tuebingen, Germany). This technology was developed for enterotomy closures for natural orifice transluminal endoscopic surgery (NOTES).

Full-thickness resection is completed using a combination of endoscopic needle knives, resulting in an enterotomy. This defect can be closed using the OTSC device. The two opposing edges of the enterotomy are brought together using a central grasping forceps known as the twin grasper. These opposing edges are drawn up into the OTSC device, and an OTSC clip is deployed to oppose the edges. If the defect closure is incomplete, closure is supplemented with endoscopic metal clips. Pure EFTR has limited applications to small lesions, given the difficulty with closing the enterotomy. Case series using the OTSC device limit the lesion diameter to less than 3 cm (Figure 10.6).^{7,13}

HYBRID ENDOSCOPIC-LAPAROSCOPIC FULL-THICKNESS RESECTION

To overcome the difficulty with closing the enterotomy, full-thickness resections can also be completed with a

hybrid laparoscopic approach. Laparoscopic and endoscopic cooperative surgery (LECS) combines endoscopic submucosal dissection and laparoscopic serosal dissection, with closure of the enterotomy defect with a laparoscopic stapling device. LECS was first investigated for local resection of submucosal tumors. In this application, ESD is completed circumferentially around the submucosal lesion, ensuring that the lesion is not violated. This is followed by full-thickness resection from the muscularis propria to the serosa around three-quarters to two-thirds circumference of the ESD dissection. The defect is closed via laparoscopic suturing or stapling.¹⁵ This technique was developed for submucosal lesions to prevent excessive removal of normal gastric tissue, especially functionally important tissues located around the esophagogastric junction or pylorus. Case series are predominantly from Japan, with an operative time of 156–172 minutes and no complications in four case series composed of 68 patients in total.¹⁶

Some authors have expressed concern regarding the potential for peritoneal spillage of malignant cells or enteric contents and its appropriateness for mucosal-based cancers (Figure 10.7).

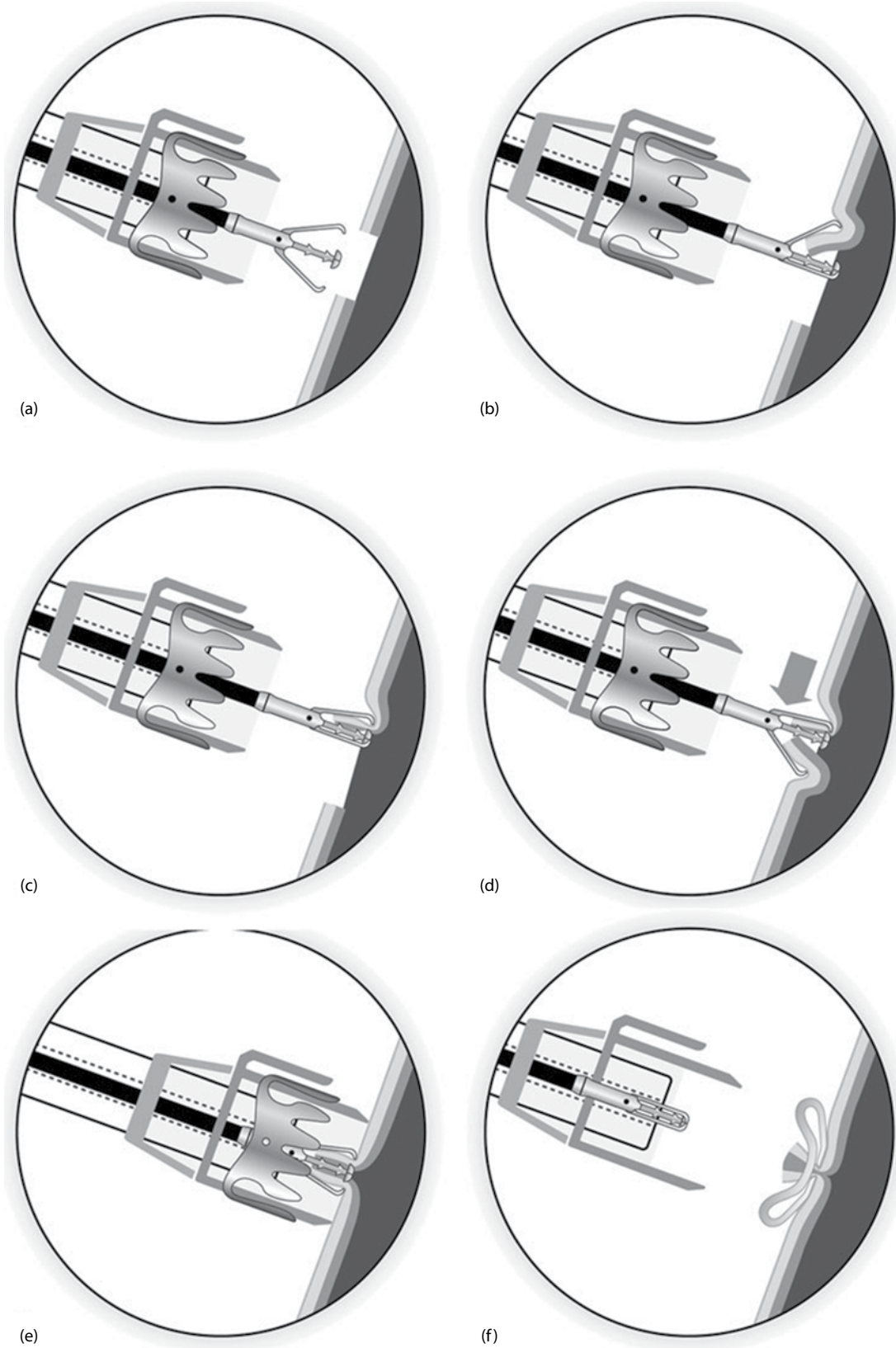


Figure 10.6 OTSC Clip application. (a–d) Grasping enterotomy edges using the twin grasper. (e) Clip deployment. (f) Final product. (From Weiland T et al. *Surg Endosc* 2013;27:2258–74.¹⁴)

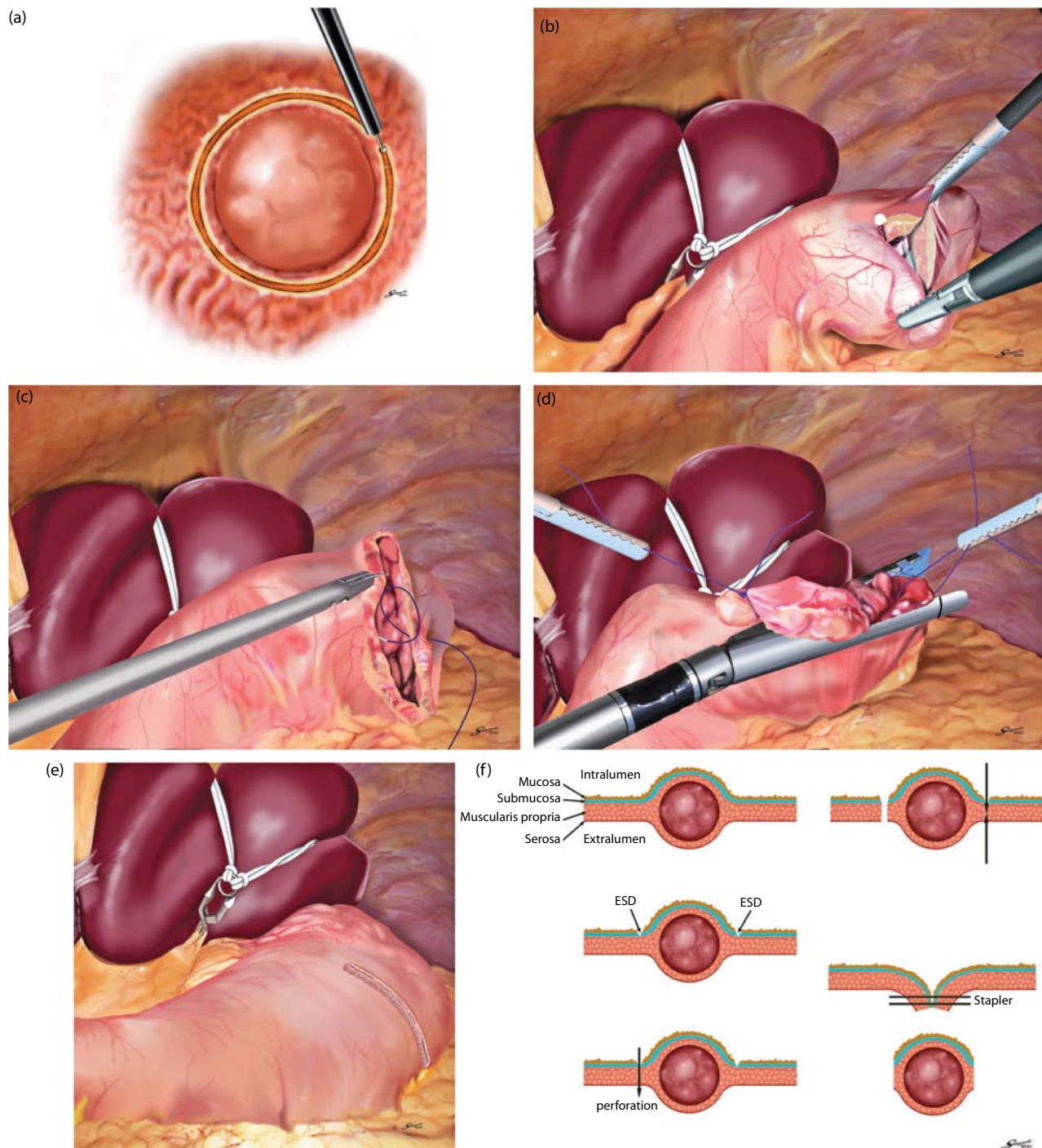


Figure 10.7 LECS procedure. (a) Endoscopic submucosal resection using the insulated tip knife. (b) Full-thickness resection using the insulated tip knife. (c) Temporary closure of enterotomy using sutures. (d) Definitive closure of enterotomy with laparoscopic stapler. (e) Finished product. (f) Conceptual diagram of LECS procedure. (From Hiki N et al. *Dig Endosc* 2015;27:197–204.)

An alternative approach to overcome the risk of peritoneal spillage is Combinations of Laparoscopic and Endoscopic Approaches for Epithelial tumors using a Non-Exposure Technique (CLEAN-NET). This is a purely laparoscopic resection with endoscopic confirmation that the tumor is encompassed in the resected specimen. In this technique, the mucosal lesion is marked out endoscopically, and four

full-thickness stay-sutures are placed circumferentially around the lesion. From here, laparoscopic seromuscular dissection takes place to encompass the stay-suture markers. Once this dissection is complete, the entire specimen is lifted by the stay-sutures, including the surrounding mucosa. The specimen is resected laparoscopically using a stapling device.¹⁶

The theoretical advantage of full-thickness resection of mucosal-based lesions over EMR or ESD is that potentially remnant cancer cells in the lymphatic or venous drainage of the GI wall are resected with the lesion, which may affect local recurrence.¹⁷ However, these techniques are still evolving, and direct comparisons with EMR and ESD have yet to be made. Full-thickness resection also has a role for patients who have undergone a previous EMR or ESD with incompletely resected mucosal-based lesions. Repeat EMR or ESD is often hindered by scarring of the plane between the submucosa and muscularis propria after a previous attempt at endoscopic resection. Full-thickness resection overcomes these challenges.

CONCLUSIONS

There is developing interest in endoscopic resection techniques for malignant lesions with a low risk of lymphatic invasion. For mucosal-based lesions, there are specific pathologic characteristics predictive of a low risk of lymphatic metastases. EMR or ESD can be utilized as an alternative to standard surgical resection and lymphadenectomy for these lesions. EMR has been widely adopted, compared to ESD, which is practiced at high-volume centers of excellence given the challenging learning curve. Although ESD has higher rates of *en bloc* resection, it has a higher rate of complications and a longer procedure time. These challenges have hindered a wider practice of ESD.

For submucosal lesions with a negligible risk of lymphatic metastases, EFTR or hybrid endoscopic and laparoscopic

techniques can be applied. Full-thickness resection techniques that prevent malignant seeding of the peritoneal are in development.

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Endoscopic procedures for morbid obesity

AUSTIN L. CHIANG AND MARVIN RYOU

INTRODUCTION

Obesity has been recognized as one of the major causes of preventable death in the world, now accounting for more deaths worldwide than being underweight according to the World Health Organization (WHO).¹ In 2014, the WHO reported obesity affecting more than 600 million individuals worldwide. In the United States, nearly 35% are obese (as defined by body mass index [BMI] ≥ 30), and nearly 17% of Americans are considered morbidly obese (BMI ≥ 40).² Recent years have seen a self-reported 70% increase in morbidly obese individuals.³ Obesity is a significant risk factor for diabetes mellitus, dyslipidemia, obstructive sleep apnea, and osteoarthritis, among other conditions. Furthermore, it also results in higher per capita health-care costs compared to normal weight individuals and as of 2008 burdened the American economy with an estimated annual cost of \$147 billion.⁴

For patients who have failed conventional methods of physical activity and dietary modification, bariatric interventions are currently offered to morbidly obese individuals or those with BMI ≥ 35 with obesity-related conditions such as hypertension or diabetes. The most commonly performed surgical approaches include laparoscopic sleeve gastrectomy, Roux-en-Y gastric bypass, and laparoscopic adjustable gastric banding. However, surgical complication rates are not insignificant; a recent systematic review of literature between 2003 and 2012 found an 11%–23% complication rate.⁵ As a result, endoscopic approaches are increasingly attractive for not only their reduced invasiveness, but also for their potential reversibility and cost-effectiveness.

According to the American Society for Gastrointestinal Endoscopy (ASGE) and the American Society for Metabolic and Bariatric Surgery (ASMBS) Task Force on Endoscopic Bariatric Therapy, the efficacy threshold for endoscopic approaches for primary obesity intervention should be 25% excess weight loss (%EWL) measured at 12 months.⁶ This

chapter describes endoscopic approaches that affect weight loss by gastric restriction, reduced absorption of digested chyme, and other novel strategies.

INTRAGASTRIC BALLOONS

Currently, the intragastric balloon is the only device currently approved by the U.S. Food and Drug Administration (FDA) specifically for primary endoscopic treatment of obesity. (At the time of this writing, the Orbera balloon and ReShape Dual balloons are FDA approved. Both are discussed herein.)

The air-filled Garren-Edwards Gastric Bubble was the first to gain FDA approval in 1985; however, the device failed to demonstrate efficacy compared to sham controls and significant obstructive complications after deflation led to its voluntary withdrawal from the market by 1992.

In the 1990s, the Bioenterics Intragastric Balloon (BIB) was developed by Allergan, Inc. (Irvine, California) and has been used worldwide in over 220,000 patients. In 2015 the FDA approved its use in the United States in obese patients with BMI 30–40 (now marketed as the Orbera Intragastric Balloon, Apollo Endosurgery, Austin, Texas) (**Figure 11.1**). The endoscopically placed balloon is filled with 450–700 mL of saline and methylene blue, which changes urine color if the balloon bursts. The balloon is intended to remain in place for 6 months and is used in conjunction with dietary counseling. In a 5-year follow-up study of 500 patients, 83% achieved %EWL greater than 20% at 6 months. While the average %EWL 5 years after removal was only 12.97%, 23% of patients (46 out of 195 total) were able to maintain %EWL $>20\%$ 5 years after removal.⁷ Although Orbera is typically implanted for 6 months, repeated balloon placement is possible and has been shown to help maintain or resume weight loss and promote improvement or resolution of diabetes, hypertension, and obstructive sleep apnea.⁸

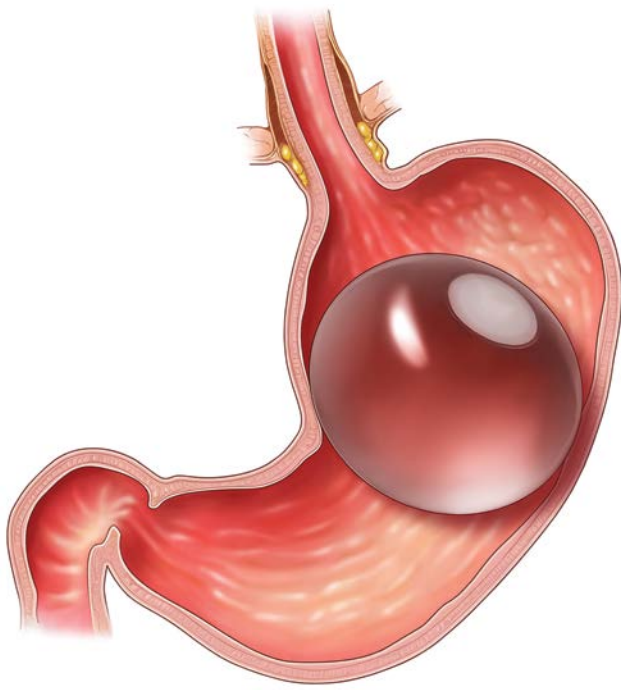


Figure 11.1 Bioenterics Intra-gastric Balloon (BIB).

The Orbera balloon has also been studied as bridge therapy prior to undergoing primary bariatric surgery, adhering to the notion that presurgical weight loss may reduce adverse events and improve surgical outcomes. However, the data have been mixed. While some studies have shown shorter hospitalization and fewer intraoperative adverse events with the preoperative weight loss achieved using Orbera, others have found no benefit of additional weight loss with the balloon preoperatively.^{9,10}

Another balloon to receive FDA approval is the ReShape Dual balloon system (ReShape Medical, San Clemente, California), where each of two balloons is filled with 450 cc of saline and methylene blue and remains in the stomach for 6 months. In a randomized prospective trial, the 6-month %EWL was 25.1% compared to 11.3% in those who only underwent dietary modification.¹¹ Other balloon devices undergoing investigation include the Spatz Balloon System (Spatz Medical, Great Neck, New York), which is the only balloon that allows for adjustment; Obalon, a swallowable balloon that fills with nitrogen but ultimately requires endoscopic removal; and Elipse (Allurion Technologies, Wellesley, Massachusetts), which is a swallowed capsule that subsequently expands into a gastric bezoar and ultimately degrades over time, thus eliminating endoscopy from both placement and removal. However, these technologies are newer, and clinical data are limited.

While intra-gastric balloons are generally regarded as very safe, with only rare occurrences of ulceration and perforation, high rates of nausea and vomiting have been reported (up to 33.7%), at times necessitating balloon removal.¹² As improvements have been made to balloon design to reduce

the incidence of ulceration and balloon migration, further modifications may improve tolerability.

SUTURING STRATEGIES

Various methods have been developed to reduce gastric capacity by apposition of opposite walls of the stomach. Some devices focus on forming plications in an attempt to reduce gastric volume. The Bard EndoCinch Suturing System (C.R. Bard, Inc., Murray Hill, New Jersey) was an FDA-approved device for tissue approximation in the esophagus and stomach and the first endoscopic suturing platform studied for weight reduction. A subsequent iteration of the EndoCinch known as the RESTORE Suturing System Device (C.R. Bard, Inc., Murray Hill, New Jersey), was developed to allow for deeper, full-thickness plications without the need for scope withdrawal and suture reloading. The RESTORE device was used in the transoral gastric volume reduction (TGVR) procedure, which involved interrupted sutures to create anterior to posterior gastric wall plications in the fundus and body, with reported outcomes after 12 months of $27.7\% \pm 21.9\%$ EWL across all BMI groups, but a high rate of partial and full plication release (83.3% of patients after 1 month).¹³

The latest iteration of suturing devices is the Apollo OverStitch endoscopic suturing device (Apollo Endosurgery, Austin, Texas), an FDA-cleared platform mounted onto a double-channel upper endoscope. The device is used in endoscopic sleeve gastropasty (ESG), a procedure that mimics the intended effect of laparoscopic sleeve gastrectomy by using a series of full-thickness sutures delivered on a curved needle to restrict gastric volume by isolating a portion of the stomach and creating a sleeve (Figure 11.2). The device allows the endoscopist to reload sutures while maintaining visualization and without removal of the scope. Recent studies describe a triangular, running stitch to approximate the anterior wall, greater curvature, and posterior wall with resultant %EWL of up to $53.9\% \pm 26.3\%$ by 6 months, as well as significant reductions in BMI and waist circumference.^{14,15} The Primary Obesity Multicenter Incisionless Suturing Evaluation (PROMISE) trial is currently underway to investigate endoscopic suturing using the OverStitch device as a primary bariatric approach.

Another plication strategy is Primary Obesity Surgery Endolumenal (POSE) procedure using the Incisionless Operating Platform (IOP, USGI Medical, San Clemente, California), which consists of a specialized four-channel overtube, through which the endoscope is passed alongside three other devices to deploy anchors through full-thickness mini-plications throughout the stomach. In 147 patients with mean BMI of 38.0 ± 4.8 kg/m², a mean total body weight loss of 16.6 ± 9.7 kg and a %EWL $44.9\% \pm 24.4\%$ was achieved after 1 year without any serious long-term adverse events.¹⁶

The durability of these strategies beyond 1 year and the potential for improved comorbid illness has yet to be fully ascertained. In the hands of an experienced endoscopist,

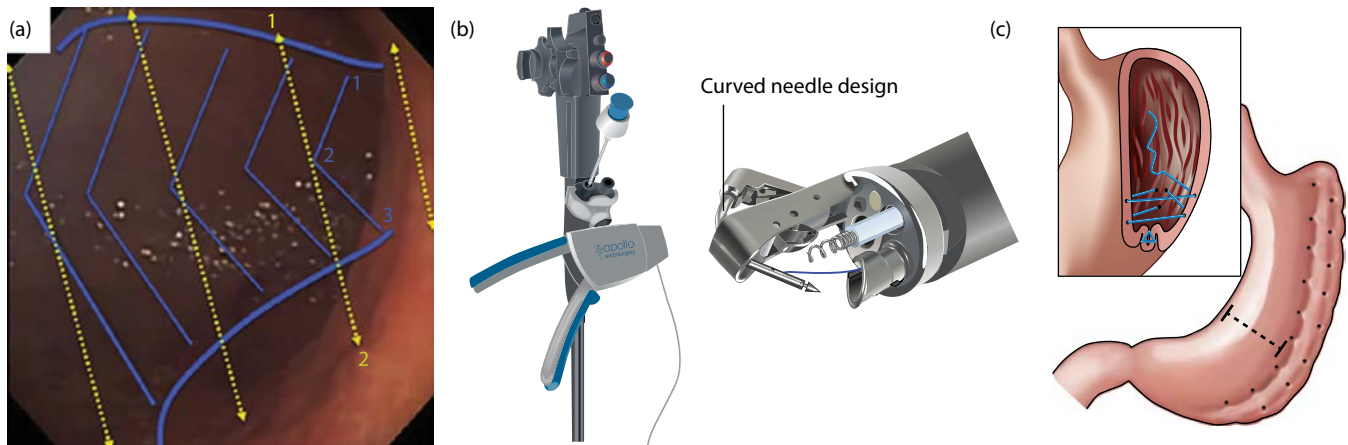


Figure 11.2 Apollo OverStitch endoscopic suturing device. (a) Suturing pattern used to create the ESG. (b) The full-thickness endoscopic suturing device used to create the ESG. (c) A longitudinal section depicting the invagination of the greater curvature of the stomach for creation of a narrow sleeve reducing the functional capacity of the stomach by 80%.

these restrictive endoscopic procedures are not only effective but also safe, as there have been no serious adverse events or procedure-related deaths reported to date.

MALABSORPTIVE STRATEGIES

The EndoBarrier (GI Dynamics, Lexington, Massachusetts), designed primarily as therapy for uncontrolled type II diabetes, is an impermeable Teflon sleeve delivered endoscopically in a capsule, which after deployment in the duodenal bulb, extends 65 cm into the proximal jejunum and is left in place for 12 months (Figure 11.3). The device allows food to bypass the duodenum and proximal jejunum, delaying absorption and mixing with pancreaticobiliary secretions. Patients were able to achieve a mean %EWL of 19.0% after 3 months (versus 6.9% for control) and a reduction in BMI by 5.5 kg/m².¹⁷ Likewise, a significant improvement of diabetes was reflected by mean reductions in hemoglobin A1c blood concentrations of up to 2.4% after 1 year.¹⁸ Despite these benefits, the pivotal American trial was terminated mid-2015, given a high incidence of liver abscesses (3.5% among 325 subjects as reported by the manufacturer).¹⁹ Plans for further study are yet undefined. While its placement requires laparoscopic assistance, the ValenTx Sleeve (ValenTx, Inc., Hopkins, Minnesota) follows a similar strategy as EndoBarrier but bypasses the stomach by extending from the gastroesophageal junction to the mid-jejunum.

ASPIRATION STRATEGIES

The Aspire Assist device (Aspire Bariatrics, King of Prussia, Pennsylvania) is a modified endoscopically placed percutaneous, silicone gastrostomy tube connected to an external device that allows individuals to aspirate one-third of a meal 20

minutes after consumption. In a pilot study of 18 patients, individuals randomized to receive the device were able to achieve mean total body weight (TBW) loss of 18.3% ($49 \pm 24.4\%$ EWL) after 1 year and $20.1 \pm 9.3\%$ TBW loss ($54.6 \pm 31.7\%$ EWL) after 2 years.²⁰ At this time, FDA approval is pending.

PYLORODUODENAL OCCLUSIVE DEVICES

The Transpyloric Shuttle (BAROnova Inc., Goleta, California) consists of a large spherical silicone bulb connected to a smaller silicone bulb, of which the latter intermittently travels into the duodenum and occludes the pylorus. Australian researchers noted 41% EWL after 6 months, though two patients required early removal due to gastric ulceration.²¹ At the time of this writing, recruitment for a multicentered randomized controlled trial is underway.

FUTURE DIRECTIONS

While some endoscopic bariatric therapies have demonstrated significant weight loss benefits, other devices seek to target obesity-related metabolic disease such as type II diabetes, even if patients might experience considerable weight loss in the process. One such device is the Revita duodenal mucosal resurfacing procedure (Fractyl Laboratories, Cambridge, Massachusetts), where duodenal mucosal cells are ablated by circumferential burning, possibly leading to alteration of enteroendocrine cell signaling and improvement in diabetes.¹² The Incisionless Anastomosis System (IAS), as the name suggests, allows for a purely endoscopic creation of an enteral dual-pathway bypass using through-the-scope, self-assembling magnets.²² Developed by GI Windows (Boston, Massachusetts), the IAS device also seeks to target type II diabetes, and

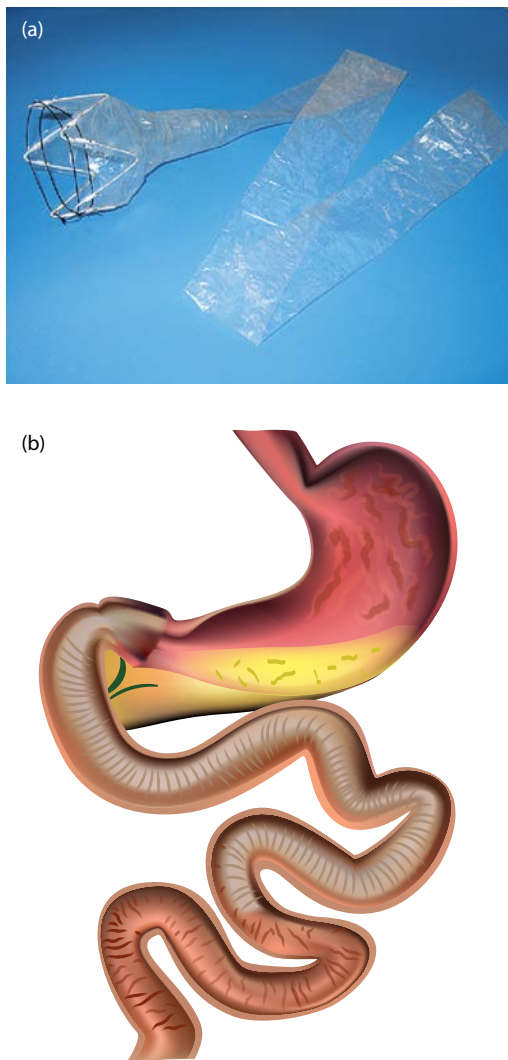


Figure 11.3 EndoBarrier. The EndoBarrier DJBS is comprised of an impermeable fluoropolymer sleeve of 60 cm and a nitinol anchor with barbs. The polypropylene drawstring is necessary for removal of the device. (b) Illustration of the EndoBarrier Gastrointestinal Liner. The device is endoscopically placed in the duodenum to form a barrier between chyme and the intestinal wall, creating a duodenal-jejunal bypass effect.

results from clinical studies are pending. Moreover, the microbiome has also been a target of study for its potential role in the pathogenesis of obesity. While likely multifactorial, various species of bacteria may differ in their ability to extract calories from certain types of food, exert certain effects on gut lining that alter barrier function, or directly modify host genes. Further understanding of the microbiome and its mechanisms may reveal potential endoscopic methods to manipulate the gut flora for the treatment of obese individuals.

The durability of weight loss and long-term outcomes of endoscopic bariatric procedures require further

investigation. Furthermore, the cost-effectiveness of these novel strategies also warrants further evaluation.

CONCLUSION

Endoscopic bariatric therapies aim to provide morbidly obese patients with a minimally invasive option of safe, effective weight loss, especially for patients who may be poor surgical candidates or refuse surgical approaches. Most endoscopic bariatric approaches have also been shown to improve comorbid conditions such as diabetes and hypertension. Long-term outcomes and cost-effectiveness of these procedures have yet to be fully understood. The FDA has seen a recent uptick in approved devices within the space (two intragastric balloons), with several more likely to gain approval in the next 12–24 months.

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Therapeutic upper endoscopy VI: Revisional bariatric techniques—Suturing, scleraltherapy

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INTRODUCTION

The incidence of obesity and morbid obesity among adults in the United States has increased to epidemic proportions during the past 20 years, such that more than one-third of the U.S. population is obese.¹ The treatment of obesity includes primary prevention, dietary measures, behavior modification, pharmacotherapy, and bariatric surgery.^{2–5} Surgical treatment of obesity has evolved and become increasingly successful, particularly since the introduction of minimally invasive techniques.⁶ Currently the most common metabolic surgical procedures include laparoscopic adjustable gastric banding, laparoscopic gastric bypass, and laparoscopic sleeve gastrectomy.⁶ Roux-en-Y gastric bypass (RYGB) has been the gold standard and one of the most commonly performed bariatric procedures worldwide. Despite excellent weight loss results, approximately 20%–30% of patients will fail to achieve their weight loss goal or regain weight.^{7,8} The options available for these patients are strict nutritional or medical weight loss programs, or revisional surgical procedures. Unfortunately, strict nonsurgical measures have proven to be ineffective in the long term.⁹ Revision by open or laparoscopic means is associated with higher morbidity and mortality compared to initial operative management, and long-term weight loss results have been inconsistent.^{10,11}

In the context of natural orifice transluminal endoscopic surgery (NOTES), recent developments of endoscopic techniques for bariatric surgery opened a new door for patients who are candidates for revisional surgery but are unwilling to accept the risk of complications associated with the complex nature of these procedures.¹² In this chapter, we sought to review two endoluminal techniques employed in

revisional bariatric surgery, suturing and scleraltherapy, and to report our own experience.

MATERIALS AND METHODS

Three independent researchers performed an advanced PubMed search combining the MeSH terms “revision” and “bariatric” and “endoluminal.” Each abstract was screened for articles in English and evaluated for relevance to the topic. Using relevant publications, a description of each procedure (scleraltherapy and endoscopic suturing) with its advantages and pitfalls is provided. In the paragraph “endoscopic suturing,” we also describe our experience using the ROSE (Restorative Obesity Surgery, Endolumenal) procedure. The potential of endoscopic therapies for revisional bariatric surgery is subsequently discussed.

SCLERALTHERAPY

Scleraltherapy attempts to increase restriction by injecting a sclerosant in perianastomotic or pouch tissue. Using an endoscopic injection needle, the sclerosing agent is injected around a dilated anastomosis. This technique was first reported in 2003 by Spaulding,¹³ who treated 20 patients by injecting an average of 6 cc of sodium morrhuate. Four years later, Spaulding et al. published a 1-year follow-up of scleraltherapy after failed weight loss.¹⁴ Of the 32 patients who had undergone scleraltherapy, 90% either lost weight or had weight stabilization; the remaining 10% continued to gain weight. No procedure-related

complications were reported. After these first studies, other authors reported their experience injecting a sclerosing agent in the years 2007–2010.^{15–17} Only 30%–64% of the patients lost weight in these series. The largest study included 231 consecutive patients undergoing 575 scleraltherapy procedures.¹⁸ The authors note that weight regain at 6 and 12 months from the last scleraltherapy procedure had plateaued in 92% and 78% of the cohort, respectively, suggesting that the beneficial effect of scleraltherapy may be transient in nature.

Scleraltherapy is a procedure with few complications that can be performed at numerous centers without the need for specialized equipment. The procedure can be repeated fairly easily if needed, which is an advantage of this approach. However, its effectiveness may be limited, with relatively modest weight loss at short-term follow-up. To date, the literature regarding this technique is limited to retrospective reviews with short follow-up.

SUTURING

In the context of NOTES, a variety of devices for endoscopic suturing have been developed and used for endoscopic revisional bariatric surgery. The idea is either to reduce a dilated gastrojejunostomy anastomosis or to reduce the gastric pouch size. The different devices and methods are described in the following text. Most devices are not commercially available today in the United States.

Bard EndoCinch suturing system

The EndoCinch suturing system (C.R. Bard, Inc., Murray Hill, New Jersey) consists of a hollow capsule that fits onto the end of an endoscope and uses suction to pull tissue into the capsule. Several sutures can be placed at the dilated gastrojejunostomy to reduce its size, or sutures can be placed at the site of a gastrogastic fistula. Schweizer was the first to report the use of an EndoCinch for bariatric surgery revision.¹⁹ He was followed by multiple researchers who also used the device for endoscopic repair of gastrogastic fistulas, resulting in a multicenter, randomized controlled trial that was published in 2010.^{20–23} In this study, 96% of patients in the EndoCinch group achieved weight loss or weight stabilization, compared with 78% in the control group. Of primary concern is the durability of the plications, as the tissue bites are not full thickness.

StomaphyX

The StomaphyX suturing system (Endogastric Solutions, Inc., Redmond, Washington) is a tissue approximation that uses a similar technique but can create full-thickness endoluminal plications. The device is designed to access the

pouch, rather than the gastrojejunostomy anastomosis. The pilot study was published in 2010.²⁴ The device was used for failed gastric bypass as well as failed vertical banded gastroplasty, but follow-up of the published series was very short.^{25,26} A major point of criticism was the difficult handling of the device.

Incisionless Operating Platform

The Incisionless Operating Platform (USGI Medical, Inc., San Clemente, California) is a multilumen system that has a channel for an endoscope and three operating channels and has been used for stoma reduction after RYGB in a ROSE procedure. The tissue-grasping device enables large, full-thickness tissue bites, allowing approximation at both the gastrojejunostomy anastomosis and within the gastric pouch. The pilot study was published in early 2009, followed by a follow-up study later that year.^{27,28} Our institution was part of the multicenter trial that was published in 2010 that included 116 patients and demonstrated mild-to-moderate weight loss with 12-month endoscopic images that confirmed anchor durability.²⁹

At our institution, 27 patients underwent a ROSE procedure. Our follow-up results, which we reported at the 2015 meeting of the Society of American Gastrointestinal and Endoscopic Surgeons³⁰ is as follows: 17 (65%) patients had weight loss after the procedure, and of these, 6 (35%) achieved more than 10% excess weight loss (EWL) and only 2 (12%) more than 20% EWL at their last follow-up. Although endoscopic plication achieved the intended reduction of the pouch and stoma diameter at 3 months, these tended to a return to preoperative diameter at 12 months. This anatomical failure may explain why most patients failed to achieve sustainable weight loss, and why the outcomes of the ROSE procedure are believed to be only moderately successful. Although stoma size has been influenced in reports, in practice, the tissue anchors are more easily placed in the gastric pouch rather than at the anastomosis; this also may partially explain its limited effectiveness.

DISCUSSION

Long-term follow-up results from endoscopic revisional procedures after gastric bypass are limited. A problem in revisional bariatric surgery literature is the inconsistent definition for failure of the primary operation. The cut-off points to delineate successful percent of EWL, and the time frames to measure outcomes after the primary operation are variable in literature. This results in conflicting reports after revisional surgery.

Endoluminal therapies to address weight regain offer the potential for meaningful impact with low morbidity. It is not reasonable to expect outcomes of an endoluminal

intervention to approach outcomes seen in conventional surgical procedures. The exact mechanisms of weight recidivism remain unclear. Several studies have correlated weight regain with anatomic variations, most notably in the gastric pouch and the proximal anastomosis. We were able to confirm this effect in our ROSE series as stoma diameter and pouch length returned to prerevisional measurements after 12 months of follow-up, which correlated with weight gain over time.

Due to the overall limited results of endoluminal therapies, much of the technology was abandoned. The only remaining commercially available endoluminal suturing device on the market is the OverStitch Endoscopic

Suture System (Apollo Endosurgery, Inc., Austin, Texas). It is used for postoperative complications after bariatric and upper-gastrointestinal surgery, although there are only meeting reports and no peer-reviewed publications on its use as a revisional strategy for weight gain.^{12,31} Timing of revisional interventions as well as the ability to repeat endoluminal therapies without major morbidity may play an even larger role when considering obesity as a lifelong disease.

CONCLUSION

Future studies should focus on methods to standardize the definitions of success and failure of endoluminal revisional bariatric surgery, and the ways in which a response to endoluminal intervention is measured and reported. As endoluminal revisions are a new field within bariatric surgery, there is great opportunity to establish benchmarks for outcomes and success.

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Therapeutic upper endoscopy VII: Management of perforations and fistula

ELEANOR C. FUNG AND DEAN J. MIKAMI

INTRODUCTION

Gastrointestinal perforations, leaks, and fistulas can arise from numerous causes such as postoperative complications after surgery (e.g., anastomotic dehiscence) or endoscopy (e.g., diagnostic endoscopy, gastrostomy tube placement) or can occur spontaneously (e.g., ulcers, tumors).¹ Regardless of the cause, they are associated with significant morbidity and mortality, especially if they lead to mediastinitis or peritonitis. The management of full-thickness gastrointestinal perforations is dependent on the severity and clinical status of the patient but has historically required a combination of admission to the intensive care unit, bowel rest with total parenteral nutrition, antibiotic therapy, drainage, and reoperation. However, the advent and success of interventional endoscopy have allowed for more conservative management as it has become an effective alternative to surgical intervention in some cases with improved outcomes and shortened length of hospital stay.² There is a wide array of endoscopic tools for effective closure of full-thickness gastrointestinal defects, and the efficacy of endoscopic interventions depends on the extent, location, appearance of the defect, as well as the timing and recognition of the defect.

This chapter reviews the principles of management of full-thickness upper gastrointestinal disruptions, the various endoscopic modalities and their efficacy, as well as evolving techniques in the management algorithms of perforations, leaks, and fistulas.

INITIAL MANAGEMENT

The success of treatment of gastrointestinal perforations, leaks, and fistula is dependent on early recognition and diagnosis, close monitoring of the patient's clinical status,

appropriate endoscopic or surgical intervention, and adequate treatment of sequelae. Following diagnosis, which can be done either endoscopically or radiologically, initial management includes bowel rest, institution of parenteral antibiotics as well as proton pump inhibitors, cardiopulmonary monitoring, and drainage of associated collections.

When perforations are detected during an endoscopic procedure, endoscopic assessment of the defect is crucial prior to closure, which includes the size of the defect, location and accessibility of the lesion, health of surrounding tissues and edges of the defect, likelihood for potential bleeding, the presence of contamination, time of diagnosis, and availability of expertise. Insufflation should be performed with carbon dioxide instead of room air, as carbon dioxide is more readily absorbed and can aid in preventing life-threatening sequelae such as abdominal compartment syndrome, tension pneumothorax, tension pneumoperitoneum, and subcutaneous emphysema.

If it is amenable to endoscopic closure, the defect should be closed immediately at the same procedure. However, if endoscopic closure fails, or in patients with severe sepsis or hemodynamic instability, surgical intervention is then required. If the perforation is detected more than 24 hours following the procedure, patients who are asymptomatic with hemodynamic stability can be managed conservatively. This subset of patients includes those who have perforations in the cervical esophagus, have gastric or duodenal perforations, and are asymptomatic with no signs of peritonitis or signs of an ongoing radiologic leak.

TOOLS AND TECHNIQUES

Current endoscopic management options for perforations, leaks, and fistulas include endoclipping, stent placement,

Table 13.1 Preferred endoscopic management according to location

Location of perforation	Preferred endoscopic closure technique
Esophagus	• Small perforations (<2 cm) can be closed with clips (TTSC or OTSC) or tissue sealants • Large perforations (>2 cm) or defects associated with stenosis may be managed with luminal stents, endoscopic suturing, or endoscopic vacuum therapy
Stomach	• Endoscopic clipping (TTSC or OTSC) or suturing • Endoscopic stents can be used to treat defects in the pylorus or gastroenteric anastomoses
Duodenum and biliary tract	• Biliary stent placement or endoscopic clips (TTSC or OTSC) can be used • Fully covered duodenal stents can also be used in nonperiampullary perforations

application of tissue sealants, endoscopic suturing devices, and endoscopic vacuum therapy. Clip application and tissue sealants are considered better options for smaller defects while endoscopic self-expanding stent placement and vacuum therapy should be used for larger dehiscences ranging between 30% and 70% of the lumen circumference (Table 13.1).³

CLIPS

Through-the-scope clips (TTSCs)

Through-the-scope clips (TTSCs) are introduced through the biopsy channel, and although they were originally used in the treatment of gastrointestinal hemorrhage, they have also functioned to provide an inverted closure of gastrointestinal wall disruptions. They are available in various designs, sizes, and widths of the opening span, which can be rotatable and re-openable to allow for appropriate closure of a variety of defects (Figure 13.1). In general, TTSCs can close luminal defects that are less than 2 cm in size. To enhance clip application, gentle suction can be applied before clip closure to allow for adequate approximation and inversion of the edges by the clip arms.⁴ TTSCs are most effective in acute iatrogenic perforations, fistulas, or leaks with a reported success rate ranging from 59% to 83%.^{5,6} Application of TTSCs can be difficult when the edges of the defect are inflamed, indurated, or in cases of chronic fistulas or leaks due to their smaller span size and low compression force.⁷

Over-The-Scope Clips

Over-The-Scope Clips (OTSCs) from Ovesco Endoscopy AG are nitinol-based biocompatible clips with the shape of a “bear claw” that is loaded on a transparent cap mounted on the tip of the endoscope (Figure 13.2). They are available in a variety of shapes and sizes (11–14 mm) according to defect characteristics with different clip tooth shapes suitable for different indications and tissues, such as traumatic (t), atraumatic (a), and gastrostomy closure (GC). The traumatic clip is more commonly used to close gastrointestinal defects, while atraumatic clips are generally preferred to control bleeding.³ OTSCs allow for a full-thickness closure that is comparable to hand-sewn



Figure 13.1 Examples of through-the-scope clips.

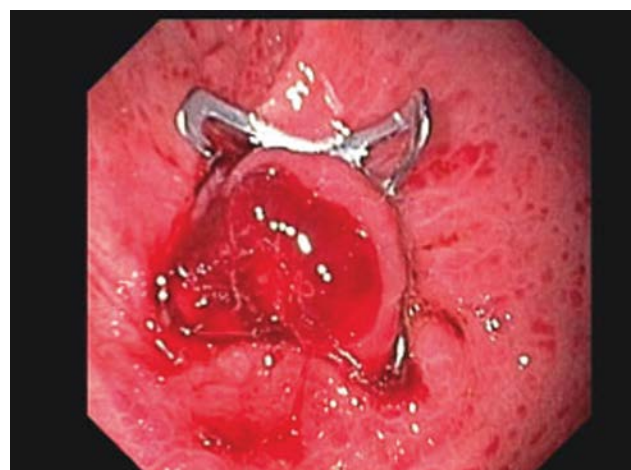


Figure 13.2 Example of an upper gastrointestinal fistula closure by an Over-the-Scope Clip.

parallel closure in *ex vivo* porcine models.⁸ The defect is pulled into the cap via suction or can be aided with a special “anchor” or “twin grasper” supplied by Ovesco. Deployment of the clip is performed via tightening of the thread connected to the clip with the hand wheel that then closes the clip to anchor firmly to the tissue, which is similar to rubber band ligation.¹ The advantages of OTSC are that they can close larger defects up to 30 mm in size and can be more effective for chronic leaks and fistulas when the tissue surrounding the defect is inflamed or indurated due to the greater compressive force and tissue capture of OTSC devices.³ The reported long-term overall success rate of OTSC ranged from 42% to 100% with a pooled overall success rate of 73%. In general, it is believed that one OTSC can be compared with results obtained with five TTSCs. The disadvantages of OTSCs are the possible risk of iatrogenic perforations due to the increased diameter of the endoscope with the mounted OTSC as well as possible occlusion of the bowel wall with the clip, but overall, the complication rate in all reported patients was found to be low at 1.3%.¹

LUMINAL STENTING

Stents have been found to be an effective and favorable alternative to surgical or conservative management of gastrointestinal disruptions, including postsurgical leaks, fistulas, and perforations in the upper gastrointestinal tract by temporarily diverting the outflow of fluid away from the defect. This allows for immediate control of leaks, protection of the gastrointestinal wall during mucosal healing, the possibility of early oral feeding, and prevention of stricture formation.⁹

Complications of stent placement occur in up to 21% of patients and can include dysphagia, hyperplasia, rupture of stent coating, bleeding, perforation, and tracheal compression.¹⁰ However, the major disadvantage of luminal stents is stent migration leading to failure of therapy, which occurs in 15%–30% of cases. Hence, following stent deployment,

frequent radiologic observation is required.¹¹ Uncovered or partially covered stents decrease the risk of migration; however, tissue in- and overgrowth can interfere with safe endoscopic removal of the stent. As such, fully covered or plastic stents are generally preferred for controlling leakage despite being more prone to dislodgement. Furthermore, in a case study of patients with esophageal leaks, there was no statistically significant difference between plastic and fully or partially covered metal stents with a success rate of 85%.¹² Factors associated with failure of defect closure include defects in the cervical esophagus, stents traversing the gastroesophageal junction, injury greater than 6 cm, and additional distal conduit leak.¹³ Strategies to reduce the risk of stent migration include the use of large-sized stents and anchoring of the stents using clips at the stent margin or endoscopic sutures (Figure 13.3).¹⁴

Stents should be removed when healing of the disruption is confirmed by water-soluble contrast examination, endoscopy, and resolution of clinical symptoms. To prevent excessive tissue in- or overgrowth, it is generally recommended that stents be removed by 6–10 weeks after treatment.¹⁵

ENDOSCOPIC SUTURING

Endoscopic suturing techniques allow for the closure of large gastrointestinal defects without injury to surrounding organs. The Apollo OverStitch system is currently approved for clinical use and allows for consistent tissue approximation with multiple full-thickness stitches in either an interrupted or continuous fashion without removal of the device between stitches (Figure 13.4). Both absorbable and non-absorbable sutures are available. The device does require a double-channel therapeutic endoscope, end cap, needle driver handle, and anchor exchange catheter. Suture placement may be facilitated with the use of a tissue-retracting helix device or grasping forceps to allow for better tissue

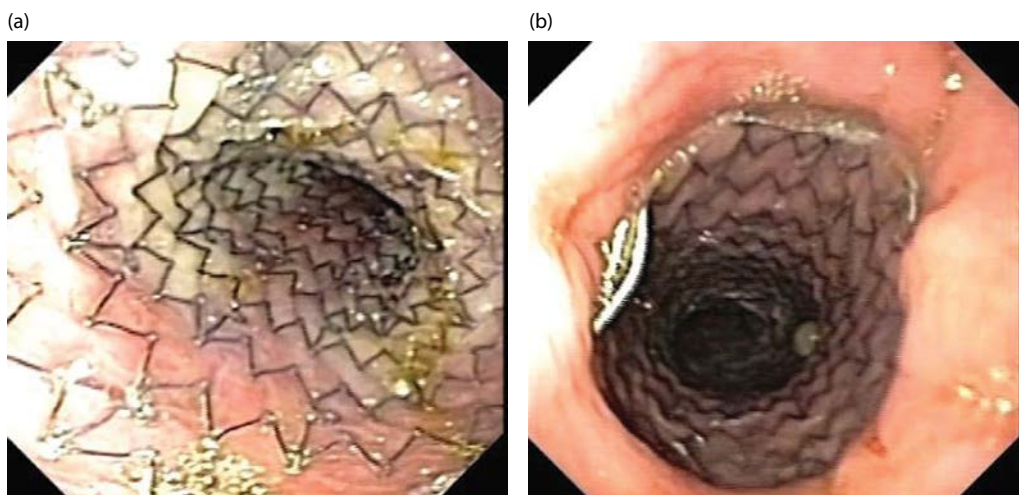


Figure 13.3 Example of esophageal stent placement secured with clips.

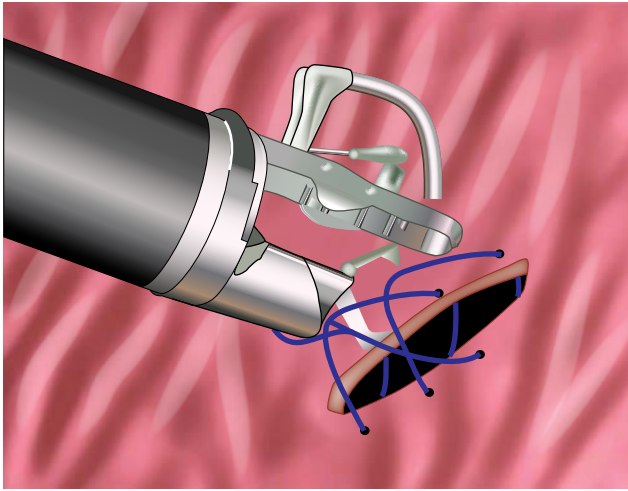


Figure 13.4 Illustration of the Apollo OverStitch Endoscopic Suturing System for endoluminal closure of full-thickness gastrointestinal defects.

apposition.¹⁶ Endoscopic suturing has been used to close both acute perforations and small chronic fistulas. Case studies have found that it has been used successfully for the closure of esophagopleural and gastrocutaneous fistulas as well as leaks after bariatric surgery. However, endoscopic suturing continues to be more technically challenging despite expertise and has had mixed results, particularly with long-term outcomes.⁷

Other suturing devices on the market include EndoCinch suturing device, SafeStitch, Medical Power System, ESD Flexible Endoscopic Suturing devices, and Eagle Claw; however, experience has been limited, and results are mixed.¹⁷

TISSUE SEALANTS

Fibrin glue and cyanoacrylate are tissue sealants that have been used to fill gastrointestinal defects for more than 20

years. Prior to application of a sealant, the mucosal edges of the defect are debrided and de-epithelialized with either a cytology brush or argon plasma coagulation to promote inflammation and facilitate healing of the defect.³

Fibrin glue is a biologic sealant composed of fibrinogen and thrombin, which is applied with a double lumen catheter to form an acellular clot in gastrointestinal wall defects that mimics blood coagulation. It is most effective when applied to a dry area, and as such, tissue remnants and pus must be removed endoscopically prior to application. In one study, complete sealing of gastrointestinal fistula with fibrin glue was obtained in 87% of cases after 2.5 sessions.¹⁸ Cyanoacrylate is a synthetic sealant that is popular to treat gastrointestinal leakage and has strong adhesive and antibacterial properties. It acts via polymerization after contact with moisture to cause tissue necrosis and an inflammatory response; as such, it has the advantage of being used in wet and infected environments. It has been reported to have been used to successfully close esophagojejunal anastomotic leaks after failed conservative therapy.¹⁹ Another benefit of tissue sealants is that they can be either applied as monotherapy or in conjunction successfully with other endoscopic techniques such as Vicryl plugs, clips, and stents.³

ENDOSCOPIC VACUUM THERAPY

Endoscopic vacuum therapy (EVT) is an emerging technique that has been used in patients with leaks associated with infections, particularly in esophageal surgery. EVT is performed by placing a custom-prepared polyurethane sponge fixed to a gastric tube directly into the defect endoscopically and applying controlled continuous negative pressure of 100–125 mmHg via the gastric tube to allow for effective drainage of the cavity, improved blood flow, reduction of edema, promotion of granulation, and inducing wound healing (**Figure 13.5**). Initial placement and subsequent regular changing of the sponge every 3–5 days can be performed under sedation until the cavity appears to be clean and the remaining wound

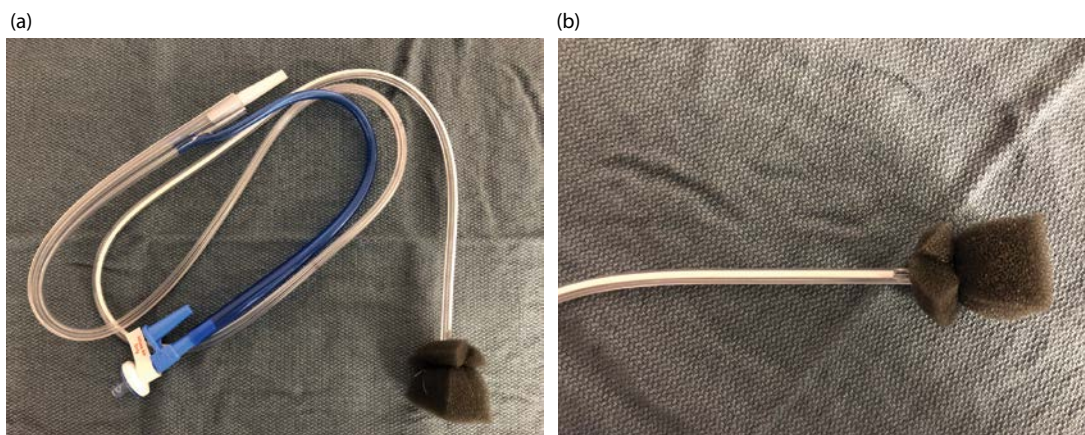


Figure 13.5 Example of an endoscopic vacuum therapy sponge attached to a nasogastric tube.

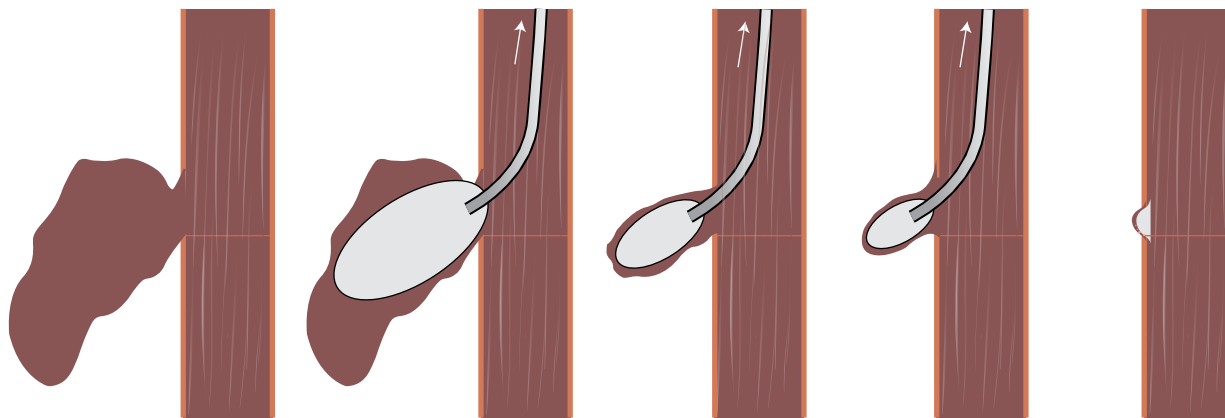


Figure 13.6 An endoscopic vacuum therapy sponge deployed endoscopically into the gastrointestinal defect to induce wound healing.

cavity is less than 1 cm radius $\times$ 2 cm in depth (Figure 13.6). Following closure, patients should be followed endoscopically once weekly until complete healing of the defect.

The main disadvantages of EVT are patient discomfort as well as stenosis after completed therapy due to scarring. However, EVT is generally effective and has been associated with good clinical outcomes in both upper and lower gastrointestinal defects. The overall success of closing upper gastrointestinal leaks by EVT was found to be approximately 90%–93%.¹

EMERGING TECHNIQUES

The cardiac septal occluder is a device typically used for the occlusion of atrial septal defects that consists of two self-expandable disks made of Nitinol mesh covered by polyester fabric connected by a short waist. Recently, this device has been used off-label for the closure of gastrointestinal fistulae. The size of the defect is measured before the occluder is implanted by passing it alongside the endoscope over an endoscopically placed guidewire under direct visualization. Both gastric leaks and esophagotracheal fistulae have been documented to be successfully closed with the cardiac septal occluder and have been used in conjunction with other techniques such as cyanoacrylate glue and clips.^{20,21}

Plugs such as Vicryl meshes and graft biomatrices such as Surgisis, which is an acellular bioactive prosthetic biomatrix derived from small intestinal sheep mucosa, have also been reported to successfully occlude gastrointestinal perforations, leaks, and fistulas endoscopically.^{22,23} Traditionally these have been used for the treatment of anal fistulas, but both have been found to be safe and effective for use in the upper gastrointestinal tract in contaminated environments with success rates of 80%–87%.⁷

There have also been limited studies on biodegradable stents in patients presenting with esophageal leaks.²⁴ The

advantages of biodegradable stents include more favorable remodeling of the esophageal wall that could reduce the risk of stricture formation as well as the lack of the need for stent removal. However, along with all of these new modalities presented, more data are still required before they are used in routine clinical practice.

POSTOPERATIVE CARE FOLLOWING ENDOSCOPIC CLOSURE

Postoperative care following successful closure of perforations, leaks, or fistulas includes parenteral antibiotics, avoidance of oral intake, intravenous fluids, analgesia, and close monitoring for signs of peritonitis and mediastinitis.

The effectiveness and success of closure after endoscopic treatment should be confirmed by radiologic exams such as contrast studies using water-soluble agents such as Gastrografin to rule out persistent leaks as well as computed tomography studies to detect extraluminal air, fluid collections, and other complications. Some patients will require surgical or interventional drainage of fluid collections to reduce septic and respiratory complications.²⁵ In order to maintain nutritional status and promote wound healing, parenteral or distal enteral nutrition should be considered in selected patients. However, if the patient has an uncomplicated postoperative course, oral intake can be resumed within 4–5 days after successful closure of perforation.³

LIMITATIONS AND COMPLICATIONS OF ENDOSCOPIC CLOSURE

While the initial results are encouraging, the biggest limitations to endoscopic management include difficulty and failure in ensuring complete closure, particularly in cases of large defects, fibrosis at the defect edges, and difficult endoscopic positioning. In these cases, incomplete closure or dehiscence

with ongoing leakage can occur, which can lead to significant morbidity from sepsis and its consequences. As such, close clinical monitoring and immediate surgical intervention are necessary in cases of clinical deterioration.²⁵ Furthermore, endoscopic techniques used for closure, such as clips, can sometimes interfere with surgical closure of the perforation.⁶

Particular to endoscopic management, tension pneumoperitoneum or pneumothorax and peritonitis can result from continued air leak and fluid spill during the prolonged time required for endoscopic closure attempts. The use of carbon dioxide during these high-risk procedures can reduce this risk, but if tension pneumothorax or pneumoperitoneum is present, emergent needle decompression is required.

CONCLUSION

Endoscopic management of upper gastrointestinal perforations, leaks, and fistulas is a promising and exciting alternative for patients who once required surgery and prolonged hospitalization. Along with proper training, further research including randomized control trials is required to determine the feasibility, clinical efficacy, and outcomes of different endoscopic techniques compared to surgical management. With new emerging technologies, the outcomes of endoscopic management of gastrointestinal perforations, leaks, and fistulas should improve and become a mainstay in the treatment algorithm of upper gastrointestinal disruptions in the future.

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Therapeutic upper endoscopy VIII: Management of upper gastrointestinal bleeding

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INTRODUCTION

Upper gastrointestinal bleeding (UGIB) is a common occurrence throughout the world. In the United States, there are approximately 400,000 hospital admissions per year for nonvariceal UGIB with a significant number of cases due to peptic ulcer bleeding.¹ While the incidence of duodenal ulcers is decreasing secondary to the use of proton pump inhibitors (PPIs) and eradication of *Helicobacter pylori*, UGIB remains common, especially from gastric ulcers that are associated with the use of nonsteroidal anti-inflammatory drugs (NSAIDs). This chapter aims to review the techniques available to the endoscopist to control UGIB. Our discussion focuses on the control of bleeding from peptic ulcers, yet it is important to know that the differential diagnosis of UGIB is diverse ([Table 14.1](#)).

INITIAL MANAGEMENT

The initial management of any patient with suspected UGIB should focus on adequate resuscitation and stabilization. A complete evaluation of the hemodynamic status of all patients should start immediately on presentation. All patients with hypotension and/or tachycardia in the setting of hematemesis, melena, and hematochezia need to be stabilized prior to endoscopic management. Intravenous access is paramount, and all patients with severe overt bleeding should have at least two large-bore (18 g or larger) catheters placed on presentation. Small-gauge central venous catheters are often inadequate to deliver appropriate rates of crystalloid or blood products and should not be placed in lieu of large-bore peripheral catheters.

The timing of endoscopy for UGIB will be dictated by the severity of bleeding and the suspected etiology on presentation. Acute variceal hemorrhage is a medical emergency, and endoscopy should be performed as soon as possible after stabilization in all patients with known liver disease and overt UGIB. In cases of peptic ulcer bleeding, the ideal timing of endoscopy is a topic of controversy. The timing should be based on the individual clinical situation, but in general endoscopy should be performed within 24 hours for all patients admitted with UGIB. Early endoscopy (<12 hours) has been shown in some series to reveal more high-risk lesions (active bleeding, visible vessel, or adherent clot) that require endoscopic therapy. In stable patients, emergency endoscopy (<6 hours) is unlikely to confer significant clinical benefit, yet delayed endoscopy beyond 24 hours likely increases hospital length of stay and associated costs.²

A number of validated scoring methods are available to assist the endoscopist in evaluating a patient for endoscopic therapy, and these include the Blatchford, Rockall, and AIMS65 scores ([Table 14.2](#)). While the usefulness of these scores in daily clinical practice is variable, there are certain aspects that can be helpful. In the case of the Blatchford score, patients with a score less than three may not require endoscopic therapy;³ patients with a Blatchford score of zero at the time of presentation can be considered for outpatient follow-up.⁴ The Blatchford and AIMS65 scores can be calculated prior to endoscopy as they do not include endoscopic findings in the score calculation.

Timing of endoscopy will be based on the individual clinical situation, but in general endoscopy should be performed within 24 hours for all patients admitted with upper GI bleeding. Early endoscopy (<12 hours) has been shown in some series to reveal more high-risk lesions

Table 14.1 Major causes of upper GI bleeding

Peptic ulcer (gastric and duodenal)
Esophago-gastric varices
Gastritis and esophagitis
Angiodysplasia
Mallory-Weiss tear
Dieulafoy lesion
Malignancy

Table 14.2 Factors comprising upper GI bleeding risk scores

Blatchford	Rockall	AIMS65
Blood urea nitrogen	Age	Albumin <3 g/dL
Hemoglobin	Shock	INR >1.5
Systolic blood pressure	Major comorbidities	Mental status
Heart rate >100 bpm	Diagnosis at endoscopy	Systolic blood pressure
Melena	Blood seen at endoscopy	<90 mmHg
Syncope		Age >65
Liver disease		
Heart failure		

(active bleeding, visible vessel, or adherent clot) that require endoscopic therapy. In stable patients, emergency endoscopy (<6 hours) is unlikely to confer significant clinical benefit, yet delayed endoscopy beyond 24 hours likely increases hospital length of stay and associated costs.²

PPIs should be considered prior to endoscopy in all patients with suspected peptic ulcer bleeding, as they may “downstage” high-risk stigmata (Figure 14.1) by the time of endoscopy and potentially reduce the need for endoscopic therapy. PPIs are an important adjunct in the management of UGIB, although their use prior to endoscopy has not been clearly shown to reduce mortality, need for surgery, or risk of rebleeding.⁵ PPIs have a significant role following endoscopic therapy of bleeding peptic ulcers. The typical

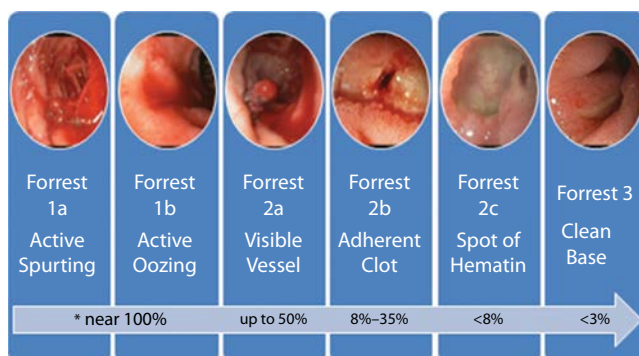


Figure 14.1 Forrest classification of peptic ulcers and estimates of rebleeding without therapy. (From Hwang JH et al. *Gastrointest Endosc* 2012;75[6]:1132–8.¹⁸)

dosing strategy following therapy of active bleeding, visible vessel, or adherent clot is a bolus dose of 80 mg followed by 72 hours of continuous infusion at 8 mg/h. This strategy has been shown to reduce rebleeding rates, need for surgery, and mortality.⁶ Recent data suggest that twice daily intravenous dosing and oral PPIs after endoscopic therapy may be noninferior to a continuous infusion.^{7,8} In patients with low-risk stigmata, including a flat pigmented spot and clean-based ulcer, beginning therapy with an oral PPI after endoscopy is adequate.

ENDOSCOPIC TECHNIQUE

Management of UGIB is one of the most frequently performed therapeutic procedures by gastroenterologists, and all should be comfortable with the basic endoscopic maneuvers required to achieve success. Visualization of the area to be treated is the first consideration when attempting to control a bleeding source. In situations of brisk bleeding, visualization will often be impaired by pooling of blood in the fundus and corpus of the stomach. There are several techniques that can be employed for improving visualization.

Prior to endoscopy, one can consider using pro-motility agents to increase gastric emptying of blood products. Intravenous erythromycin is an antibiotic that has affinity for the motilin receptor and can assist in gastric emptying. A one-time dose of intravenous erythromycin 250 mg can be considered 20 minutes to 2 hours prior to endoscopy. Data from randomized controlled trials suggest that erythromycin improves visualization, decreases the time of endoscopy, and may reduce the need for a second endoscopy during the index hospitalization, although there is some discordance between studies with small sample sizes.^{9,10} Gastric lavage using a large-bore orogastric tube (40F, Ewald) can be considered prior to endoscopy. One can also choose to use a large-channel “therapeutic” endoscope to suction larger clots. The available evidence suggests that visualization of the gastric mucosa may be improved in the fundus but may not increase the odds of finding and controlling a bleeding source.¹¹ Many endoscopists also find that repositioning the patient from the standard left lateral decubitus position to a more supine position may improve visualization at the expense of increasing the technical difficulty of the procedure. When an area of active bleeding is identified, the endoscopist has many tools in his or her arsenal to achieve hemostasis. Here we review the most commonly employed tools including epinephrine injection, bipolar electrocautery, endoclips, and argon plasma coagulation (APC).

Epinephrine

Injection of epinephrine is one of several options for hemostasis in acute upper GI bleeding. Injection is often part



Figure 14.2 Epinephrine injection of an actively bleeding ulcer base.

of a dual-therapy approach in upper GI bleeding; it is less frequently employed as monotherapy, and we suggest this be avoided in most cases as it may be associated with an increased risk of rebleeding compared with dual therapy.¹² Epinephrine (1:10,000 dilution) comes in prefilled syringes that are compatible with most commercially available injection devices. There are many commercially available needle tip catheters that pass through the instrument channel of the gastroscope.

Epinephrine works through two mechanisms. The first and most important mechanism for halting arterial bleeding is local tamponade, while vasoconstriction likely plays a minor role.^{13,14} In the case of a bleeding ulcer, we typically identify the ulcer margins and proceed to inject 1–2 cc in each of four quadrants within 5–10 mm of the bleeding site (**Figure 14.2**). In the case where there is a visible vessel or active bleeding, we typically then inject 1–2 cc directly in the center of the ulcer to enhance the tamponade effect. This process can improve visualization and in many cases will stop the active bleeding temporarily. It is common to see surrounding tissue pallor in the area surrounding the ulcer. We typically do not inject more than 20 cc of epinephrine to avoid the potential for systemic complications such as tachycardia and local tissue necrosis, although some studies suggest that higher volumes may be tolerated.¹⁵ Following the injection of epinephrine, we then use a second method of hemostasis, most commonly bipolar electrocautery or endoclips.

Bipolar electrocautery

Bipolar electrocautery is commonly used following injection of epinephrine, which may have helped to identify an underlying vessel for treatment. The bipolar probes will deliver a low energy impulse through the end of the catheter, which contains a completed circuit; therefore, the probes do not require the patient to be grounded

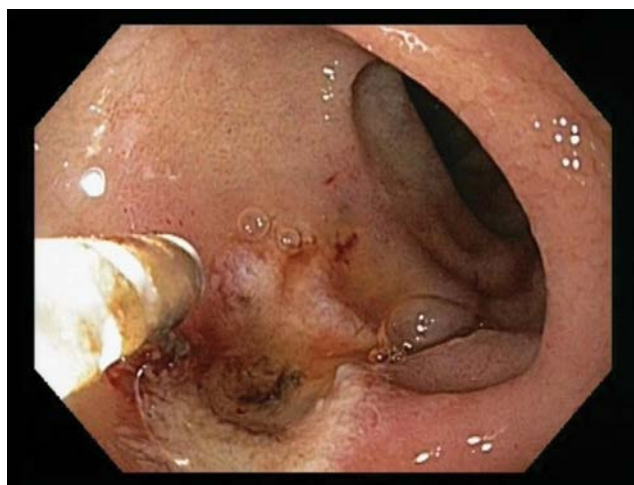


Figure 14.3 Bipolar electrocautery applied to an ulcer base following epinephrine injection.

with a pad. These probes generate heat by passing current through tissue, and an applied pressure will cause coaptation or the joining and sealing of the vessel wall. Many of the commercially available probes also come with an integrated injection needle and a water port so that the endoscopist can inject a site with epinephrine, wash the site, and then apply thermocoagulation without needing to exchange devices through the instrument channel. Bipolar electrocautery is safer than monopolar current, as the depth of tissue damage is shallower and the maximum temperature is lower.

We typically start at a power setting of 18–20 W for therapy of bleeding ulcers. In order to achieve coaptation of vessels, the pressure and energy should be applied firmly to the ulcer base for up to 8–10 seconds. This process can be repeated until adequate hemostasis is achieved, and typically we use three to five cycles (**Figure 14.3**). Coagulated and desiccated tissue may interfere with the current needed to heat the area. In the case where tissue accumulates on the end of the catheter, it should be removed, cleaned with gauze, and reintroduced. Typically we use probes that are 2.3 mm (7 French) in diameter and will work well through the instrument channel of a standard diagnostic endoscope which is 2.8 mm. A 3.3 mm (10 French) probe will require a larger therapeutic endoscope with a working channel of 3.7 mm.

Endoclips

Endoclips are small, metal clips attached to a wire within a plastic-coated sheath. These clips are placed into the instrument channel of the gastroscope. A handle found on the exterior portion of the catheter is used to open, close, and advance the metal clip from the sheath. There are a number of commercially available clips with a jaw size that ranges from 9 to 12 mm, and several models can be rotated 360° to achieve precise clip alignment.¹⁶ The clips are typically

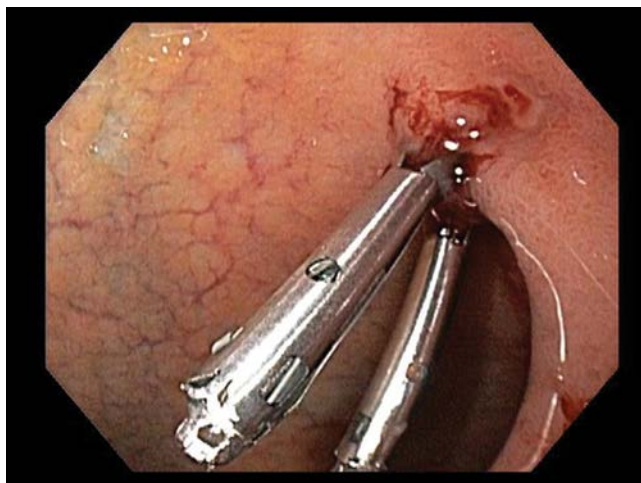


Figure 14.4 Endoclips used to control a bleeding ulcer in the duodenal bulb. (Image courtesy of Dr. Katherine Germansky.)

deployed by fully compressing the handle until an audible click is heard indicating the clip has been successfully closed. Endoclips have been shown to be equally as effective as bipolar electrocautery with epinephrine injection in control of peptic ulcer bleeding.¹⁷ It is important to note that endoclips require precise tip control of the endoscope, and success depends on the skill of the endoscopist to deploy clips directly over the vessel. In many cases, several clips will need to be deployed to achieve adequate hemostasis (Figure 14.4).

Argon plasma coagulation (APC)

APC has been shown to be effective in treating a number of bleeding lesions in the upper GI tract. APC is not frequently used in the management of bleeding peptic ulcers, but there is evidence to suggest that it may be as effective as thermal coagulation.¹⁷ We use APC most frequently in the setting of upper GI bleeding related to angiodysplasia and gastric antral vascular ectasia (GAVE). APC works by delivering a monopolar current through a column of ionized argon gas causing tissue coagulation. This is a noncontact modality, and the probe is often placed 2–8 mm from the surface to be treated prior to depressing the foot pedal to deliver current. Caution must be taken to avoid direct contact with the tissue, as this can cause a deeper injury and may increase the risk of perforation.

Band ligation

Band ligation is the initial treatment of choice for active bleeding from esophageal varices in the setting of portal hypertension from liver disease. Variceal bleeding can often be torrential, and one must ensure appropriate hemodynamic stabilization and airway maintenance prior to endoscopy. The commercially available band ligation devices will cover the tip of a standard gastroscope with a plastic cap and will typically be able to deploy between 6 and 10 bands. When a varix is identified, the tip of the scope is positioned over the varix, and maximum suction is applied until the varix is within the banding chamber. A band is then deployed using the firing device mounted to the instrument channel of the gastroscope.

Endoscopic therapy for UGIB has evolved substantially over the last few decades. The number of tools in our arsenal has grown, and now a well-trained endoscopist has several options to employ when treating an active bleed. We recommend that every endoscopist become familiar with the specifications of the equipment available at their institution, and if appropriate, seek advanced training in techniques of hemostasis.

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Diagnostic lower endoscopy I

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INTRODUCTION

Colonoscopy is an invaluable tool for evaluation of the large intestine and distal ileum, providing direct visual examination of the mucosa and lumen and facilitating microscopic study of tissue obtained by biopsy. In this chapter, we focus on the various elements that make diagnostic colonoscopy as safe, effective, and comfortable as possible. Therapeutic interventions are reviewed in subsequent chapters.

INDICATIONS

The most common symptoms that prompt diagnostic colonoscopy are unexplained diarrhea and intestinal bleeding, including hematochezia, guaiac positive stool, iron deficiency, and melena without a defined upper gastrointestinal (GI) source. Symptoms of altered bowel function, constipation, and abdominal pain often prompt referral for colonoscopy, but because the yield for these diagnoses is low, one should consider if the severity of the symptoms is significant and if the study results are likely to change therapy. For example, patients with symptoms typical for irritable bowel syndrome can usually be diagnosed by Rome criteria⁶² and do not require colonoscopy unless there are warning symptoms of more serious disease.^{63,64} Colonoscopy is an integral part of the evaluation of inflammatory bowel disease, both in making the initial diagnosis and for helping to manage the disease. Other indications for colonoscopy are evaluation of a radiologic abnormality (polyp or mass, mucosal changes, thickened wall, stricture), fever of unknown origin, *Streptococcus bovis* bacteremia (which is frequently associated with colon lesions), an unexplained elevated carcinoembryonic antigen (CEA), or suspected occult malignancy in a patient with metastatic adenocarcinoma of unknown primary or with symptoms suspicious for malignancy. Patients newly diagnosed with an adenoma

or malignancy should have a full colonoscopy to search for synchronous lesions elsewhere in the colon. The procedure also can localize the site of pathology for surgery, either by preoperative application of a tattoo or by intraoperative colonoscopic visualization. A comprehensive list of indications for colonoscopy is available from the American Society for Gastrointestinal Endoscopy.¹

Colon cancer screening and prevention have become the dominant indication for performing colonoscopy. This is accomplished by detecting colonic adenomas and removing them before they transform into adenocarcinoma. The lifetime risk of developing an adenoma is about 40%,² and the risk of developing adenocarcinoma is about 4.5%.³ Colonoscopy with removal of all polyps has been demonstrated to reduce the risk of carcinoma.^{4,5} Current guidelines suggest beginning screening at age 50 for patients at standard risk,⁶ but patients at higher risk may be advised to begin at an earlier age. The American College of Gastroenterology recommends age 45 for African Americans.⁷ Patients with a family history of cancer should begin screening at an age 10 years younger than the age their relative developed cancer.^{4,7} Familial adenomatous polyposis and hereditary non-polyposis cancer syndrome (HNPCC, or Lynch syndrome) carry the highest risk, so a patient with a positive genetic test, or one who has not been tested but has a family history strongly suggestive of an inherited risk, should be screened beginning in the second decade of life for familial adenomatous polyposis,⁸ in the third decade for HNPCC,⁹ or 5 years before the age of the youngest affected family member for both conditions. Recent recognition of an increasing occurrence of colon cancer in patients younger than 50 years¹⁰ should remind clinicians to pay careful attention to any clues in a patient's history that might be concerning.

Intervals between screenings should reflect the natural history of polyp formation and progression to cancer, which usually takes 10 years or more. For standard risk patients who have had a normal colonoscopy, 10 years is

the recommended interval. For those who have adenomas detected, or for patients with a higher risk, such as family history, 5 years is appropriate. Patients with multiple polyps (greater than three significant-sized lesions) or with advanced adenomas (size greater than 10 mm, villous histology, or high-grade dysplasia) should return in 2–3 years, or sooner if the risk appears high. Larger adenomas or those with dysplasia found at the histologic margins may require a follow-up in 6–12 months.¹¹ Patients who have had an adenocarcinoma resected are at higher risk for metachronous neoplasms and so should have frequent surveillance, initially 1 year after surgery and then at progressively longer intervals up to a quinquennial schedule for the rest of their life.¹²

Both Crohn's colitis and ulcerative colitis increase the risk of cancer proportional to both the duration of disease and extent of involvement of the colon. Recommendations are to begin screening patients with inflammatory bowel disease (IBD) with colon involvement after 8 years of disease and continue screening every 1–3 years thereafter.¹³ In addition to a visual search for neoplasms and abnormal mucosa, often aided by chromoendoscopic staining techniques, multiple random biopsies are taken throughout the colon in search of dysplasia, which may be the first detectable indication of progression toward carcinoma.

The risk of colon cancer increases with age, but the risk of colonoscopy is also somewhat higher in later years. In general, patients whose life expectancy is less than 10 years are not likely to benefit from a procedure, so expected longevity as well as comorbidities should be considered when selecting patients over 75.⁶

PATIENT SELECTION

Most patients are good candidates for colonoscopy, but comorbidities that increase the risk of the procedure should prompt careful evaluation of the risk-benefit ratio. All risks should be considered, including those associated with bowel preparation and sedation, as well as those from the procedure. Patients with cardiac disease, vascular compromise, especially in the carotids, pulmonary disease, diabetes, renal or liver failure, sleep apnea, morbid obesity, those on anticoagulants, and older patients may be at higher risk. Consultation with a specialist or anesthesiologist can help evaluate the safety of proceeding. Relative contraindications include suspected visceral perforation, active diverticulitis, and fulminant colitis.

The risks and benefits of alternative tests should also be weighed, such as a barium enema, computed tomography (CT) colonography, magnetic resonance imaging, or an oral capsule camera (PillCam 2⁴⁵), as they may be more appropriate choices in some circumstances. CT is most commonly used as an adjunct when colonoscopy fails to reach the cecum, but it may be used as an alternative screening method for patients who are poor candidates for colonoscopy or who express a preference for CT.

PREPARATION

Preparation for the procedure includes advanced communication with the patient, advanced planning for certain conditions, a vigorous cleansing of the bowel by means of dietary restriction and laxatives, a preprocedure evaluation immediately prior to the procedure, and procurement of informed consent.

Communication

Communication with the patient should be in written form and should include clear instructions about date and arrival time, diet, laxative cleansing regimen, adjustment of medications prior to and on the day of the procedure, and details about their responsibility to arrange transportation and payment. They should be instructed to consult their specialist if they have renal failure, diabetes, or are on anticoagulants. Information about what to expect during the procedure and a sample low-residue diet can also help prepare the patient. Despite use of written instructions, as many as 20% of patients may arrive for the procedure inadequately prepped, which results in a poorer quality study or cancellation.¹⁴ This may be due to failure to receive the instructions, failure to read them, language barrier, or failure to carry through. Successful techniques to reduce the rate of inadequate preparation have included video instructions,¹⁵ availability of instructions online, and patient “navigators” who call or visit patients and walk them carefully through the instructions in advance.¹⁶

Advanced planning

Special attention and communication are required for patients with certain comorbidities, including renal failure, diabetes, and anticoagulation. Those with moderate to severe renal failure should avoid magnesium laxatives; polyethylene glycol is preferred. Diabetics may require adjustment of their insulin or oral agents. On the day prior to the procedure, the clear liquid diet provides adequate calories to permit usual dosing, but on the day of the procedure, it is common to omit oral agents or administer half a dose of insulin, then resume dosing when the patient begins eating again. It is best, if possible, to schedule diabetic patients in the morning. Patients on anticoagulants and antiplatelet agents can undergo diagnostic colonoscopy without any increased risk.⁶⁵ For those who may need an intervention, the concern about potential bleeding requires an analysis of the relative risks of bleeding (lowest for diagnostic procedures with simple biopsies or removal of small polyps, highest for more advanced procedures that involve extensive mucosal disruption) and the risk of complications related to stopping the anticoagulant (cardiovascular or central nervous system or vascular events). Ideally, there should be communication well in advance of the procedure between

the colonoscopist, the primary physician, and the specialist who recommended the anticoagulant, as well as the patient in some circumstances. An institutional system to facilitate that discussion will help avoid unnecessary risk. When it is considered best to stop the anticoagulant, it is usually stopped 3–5 days before the procedure and restarted 2–3 days afterward. The complexities of this decision are thoroughly reviewed in an American Society for Gastrointestinal Endoscopy Standards of Practice publication.¹⁷

Other medications should also be reviewed. Iron supplements should be stopped a week before the procedure, as remnants of the dark pigment may diminish visibility. Prophylactic antibiotics are not recommended for diagnostic colonoscopy, even for patients with high-risk conditions, since bacteremia is negligible.¹⁹ Some guidelines recommend prophylaxis for patients on peritoneal dialysis or who have severe neutropenia or hematologic malignancies, though studies to support this are lacking.^{18–20}

Bowel preparation

Adequate cleansing of the bowel is paramount to provide unobstructed views of the mucosa. The first step is dietary restriction of high-fiber foods, especially nuts and seeds, which should be done for 3–5 days before the examination, followed by a clear liquid diet the day before the exam. For safety during sedation, patients should take nothing by mouth for 2 hours before the exam. More stringent restrictions may be required for anesthesiologist-administered monitored anesthesia and should be conveyed to the patient in advance. The next step is a thorough flushing with laxatives. There are numerous laxative regimens in use, most commonly osmotic agents such as a salt or polyethylene glycol, all of which are effective and safe, but none of which have achieved universal tolerability. Better results are obtained by splitting the laxative into two doses, and by giving the second dose as close as possible to the time of the procedure, usually 6 hours before.²¹ Poor results are more common in patients who are constipated, elderly, bedridden, have parkinsonism or diabetes, or take medications that slow intestinal motility, such as narcotics or psychotropic agents.²² If a patient has had previous problems preparing, an effective practice is to require 2 days of clear liquids and potentially also add an additional laxative two nights before the procedure. A newer alternative approach to cleansing is colon hydrotherapy, which can thoroughly flush the colon without any advance dietary or laxative preparation.

Pre-procedure assessment

On the day of the examination, the colonoscopist should take a focused history, confirm with the patient what will be done during the procedure, review any special consideration such as management of anticoagulants, and answer

any questions or concerns the patient may have. This meeting offers an opportunity to establish rapport with a previously unknown patient and to provide reassurance to familiar patients, an encounter that can foster confidence in the colonoscopist so that the patient will be more relaxed, potentially easier to keep comfortable, and likely to have a more satisfactory colonoscopy experience. For patients with psychological issues, especially post-traumatic stress disorder from childhood abuse, sympathetic acknowledgement of their fears is helpful, and it is often useful to ask them specifically if they have concerns about loss of control during anesthesia or about insertion of the scope.⁶¹

Informed consent

Obtaining informed consent requires a discussion of both benefits and risks. At a minimum, mention should be made of bleeding, organ damage, and side effects of sedation as possible risks. A more extensive discussion may be preferred by some physicians or patients and might include nausea, postprocedure pain, allergic reactions, arrhythmias, respiratory compromise, blood transfusion, perforation, hospitalization, emergency surgery, and missed lesions.

Time out

It has become standard procedure to do a final check just prior to beginning the procedure, during which the team verifies the patient's identity using two forms of identification, confirms the procedure being done, and reviews any special considerations, such as anticoagulants, allergies, and code status.

SEDATION

Most diagnostic colonoscopies are performed with moderate sedation, using a combination of a benzodiazepine (Versed) and a narcotic (fentanyl) to reduce anxiety and minimize discomfort. The choice of agents should avoid potential interactions with other medications, especially HIV medications and monoamine oxidase inhibitors. The dose is titrated while monitoring blood pressure, oxygen saturation, breathing pattern, and level of patient comfort. Although many patients can be safely sedated so that they are unaware and amnesic for the procedure, others may remain awake, either because they are resistant to these medications or because they prefer lighter sedation. If a patient cannot tolerate the procedure with moderate sedation and requests it to be stopped, the test should be terminated and plans made to reschedule with anesthesia.

A second option is Monitored Anesthesia Care (MAC), typically using propofol. This is becoming more popular because it is universally effective for amnesia and pain relief, has a more rapid onset and rapid recovery time, and results in

faster turnover times in the endoscopy suite and a lower rate of post-procedure nausea.⁶⁷ The disadvantages of MAC sedation are a slightly higher risk of aspiration associated with propofol²³ and additional cost associated with the need for a second practitioner to monitor the patient for hypoventilation.²⁴

Some patients request an unsedated procedure, which can be well tolerated.²⁵ Success is dependent partly on an anatomy with few sharp angles, partly on a patient's intrinsic tolerance for discomfort and the patient's willingness to accept an occasional cramp, and partly on the colonoscopist using techniques to minimize distension and stretching.²⁶

PROCEDURE TECHNIQUES

The first phase of colonoscopy is advancement of the scope to the cecum and terminal ileum, or as far as can be reached, during which the focus is on accomplishing intubation in the most comfortable and safe manner possible. The second phase is a careful withdrawal, during which a thorough evaluation of all surfaces is accomplished. There is little evidence-based literature regarding techniques, so the following discussion is largely based on an experiential consensus of clinicians.^{58,68}

Patient position

The most common patient position is the left lateral decubitus position. In most circumstances, the procedure can be completed without changing the patient's position, but sometimes a shift to a prone or supine position or to the right side can change the shape of the bowel and facilitate negotiating difficult segments or flexures. One study suggests initial placement in a right lateral decubitus position allows for more rapid cecal intubation.²⁷ Another study suggests that patients with a high body mass index require repositioning less commonly and have shorter intubation times if they start in a nearly prone position.²⁸ Patients with colostomies are done in the supine position.

Advancement phase

After initial visual inspection of the anal verge for hemorrhoids, tags, condylomata, or tumor, the anal passage is lubricated (xylocaine gel is useful if the patient has anal sensitivity or inflammation), and the prostate is digitally examined. The scope is then carefully inserted into the rectum. Air or CO₂ or water is used to insufflate the lumen for visualization. Air is by far the most common agent used. CO₂ offers an advantage of more rapid absorption and therefore fewer adverse effects,²⁹ but most centers do not find the advantage worth the additional cost and effort. Water can also be used to distend the bowel, and its use has been shown to cause less pain in lightly sedated patients³⁰ and may make it easier to pass through tortuous areas, especially the

sigmoid, where air pressure may cause comparatively more exaggeration of sigmoid tortuosity. Although some endoscopists choose to use water exclusively, most often it is used intermittently when needed to facilitate passage through a difficult turn or tortuous area. Excessive distension by either gas or water can induce pain and vagal stimulation, so to increase comfort and safety, frequent suctioning should be done as the scope is advanced.

Scope advancement is often fairly easy, requiring only gentle forward pressure on the shaft and manipulation of the tip to steer the scope through the visualized lumen. The tip can be directed in four directions with the cabled wheels and also by torquing the scope clockwise or counterclockwise. Tip deflection is greatest in the upward direction as seen on the screen, so a helpful technique is to rotate the scope so that the direction of travel is upward. Simple maneuvers to help advance include shortening the colon by suctioning air and torquing the scope, most often clockwise, to reduce redundant segments. Another helpful technique is to reconfigure the colon anatomy by either external pressure or by repositioning the patient to a semi-prone or supine position, utilizing gravity to shift the bowel. Passing the scope from the midascending colon into the cecum is often facilitated by some combination of suctioning air, applying external pressure to the midtransverse colon under the xiphoid, and/or rolling the patient either forward or supine. With scopes that offer variable stiffness, adding stiffness to the shaft can sometimes help advancement.³¹

Finding the lumen

Keeping the lumen in view can be challenging when the lumen is tortuous or obscured by retained fluid. Suctioning the fluid, though a tedious task, is often crucial to allow visualization and should be done aggressively whenever progress is impaired. Losing sight of the lumen requires time to reorient, so keeping the lumen in view should be a goal. This is best done by advancing more slowly through tortuous areas, keeping at least part of the lumen in view while redirecting the tip to maintain sight of the lumen. If the lumen has been lost, the most effective technique to relocate it is to withdraw the scope a few millimeters or centimeters until a mucosal landmark or lumen is identified again. Learning to read mucosal clues is helpful. For example, the concave side of a haustral fold usually points perpendicularly toward the lumen. Also, when withdrawing, the direction in which the mucosa appears to be moving is usually where the lumen can be located. Negotiating a tortuous segment with numerous diverticula and poor luminal distension is a common challenge. Diverticular openings are typically smooth, whereas subtle pleats of mucosa indicate the lumen direction. Understanding the zig-zag pattern created by haustra on alternating sides of the lumen can ease navigation, as for example, after turning left, the lumen is next likely to be found toward the right. When the lumen curves away sharply and is not visible,

pulling back slightly and adding left or right tip deflection or torque may bring the next section into view. Sometimes the scope may need to be advanced blindly with a “slide by” technique. This should be done slowly and gently and aborted if the examiner senses increasing pressure, the patient expresses pain, there is blanching of mucosal blood vessels, or the tip stops moving along the mucosa.

The unruly colon: Redundancy, angles, and loops

Often the scope does not advance easily, due to redundancy, angles, and loops that prevent forward pressure from translating into advancing the tip. Redundancy and angles are caused by the flexibility of the colon on its mesentery, which allows the wall to deform as the scope is advanced. It is especially problematic at the flexures but can also occur in a tortuous sigmoid or if the transverse colon drops inferiorly in the abdomen. Pushing forward may worsen the sharp angle, and continued aggressive attempts may cause mucosal or mesenteric damage. So the scope should be slowly withdrawn to straighten the deformed colon, and the tip should be carefully manipulated through the mucosal folds. Removing air can help, and infusing water may provide better visualization and help soften the angulation. Occasionally, a sharp angle between the descending and sigmoid colon can be more easily negotiated by repositioning the patient to a supine or right-sided position or by externally manipulating the sigmoid in the left lower quadrant, pulling it toward the umbilicus. Similarly, an acute 180° angulation at the splenic flexure due to redundancy of the distal transverse colon may require repositioning to a supine or right lateral position or external pressure to push the colon upward.

Formation of loops in the sigmoid and transverse colon is another common problem. Clues to this include failure of the tip to advance, retrograde (paradoxical) movement of the tip, excess pressure felt during advancement, and patient intolerance expressed as pain or vagal-induced bradycardia. When this happens, the scope should be withdrawn, using a clockwise or counterclockwise torque in hopes of reducing the loop and shortening the bowel. Often the operator can sense a relaxation in the shaft of the scope as the loop is reduced, following which forward motion can be more easily accomplished again. Sometimes, loops do not reduce easily or may reform when the scope is advanced again. In these circumstances applying external pressure may keep segments straighter.⁵⁸ It is possible to form a loop in a large inguinal or ventral hernia, in which case external pressure is essential.

To minimize the chance of creating loops during insertion of the scope, it is good practice to repeatedly withdraw the scope short distances, even when resistance is not encountered, as this will help telescope the bowel over the scope, thereby shortening its length and reducing the tendency for looping. In most circumstances, this will result in shortening the colon from its natural 150 cm length to

60 or 70 cm, as measured by the length of scope needed to reach the cecum.

Intubation of the terminal ileum

Entering the terminal ileum should be attempted for all patients with bleeding, diarrhea, right lower quadrant pain, or radiologic abnormalities that require evaluation. Evaluation during routine screening colonoscopies has a low yield of pathologic findings, however, so it is commonly omitted during cancer screening procedures.⁵⁹ The valve appears as a thickened or flattened area on the first haustral fold, and when the opening is seen, the scope can be directed into it fairly easily. More commonly, however, is for the opening to be hidden on the anatomically proximal side of the fold, in which case its position is usually aligned with the apex of the appendiceal opening, and intubation is accomplished by pulling the scope backward from the cecal cap with the tip angled upward, catching the opening with the tip. Once the valve has been entered, turning the tip slightly clockwise will usually locate the direction of the lumen. A third technique is to retroflex the scope in the cecum, identify the opening, and then carefully pull back, directing the tip of the scope into the valve, then straightening the tip of the scope once the ileum has been entered.⁶⁰

Withdrawal phase – a thorough examination

The focus now turns to a systematic and thorough examination of all surfaces. The most common findings are neoplasms, diverticula, and hemorrhoids. Others are inflammatory changes (loss of vascular pattern, erythema, aphthoid erosions, ulcerations, strictures, scarring, and pseudopolyps), arteriovenous malformations (AVMs), submucosal lesions such as lipomas or leiomyoma or gastrointestinal stromal tumors, ischemic changes including necrosis, condylomata, and fistula openings. A skilled endoscopist should recognize subtle changes in mucosal color and texture as well as more obvious surface elevations typical of polyps. For example, an important clue to a possible underlying sessile serrated adenoma is a mucus cap⁵⁵; any adherent patch of mucus should be lavaged clear followed by a careful look at the mucosa.

The most important factor for a thorough examination is visualization of all surfaces. The mucosa should be clean, sometimes requiring copious use of the water jet and suction to remove residual fluid and debris. If air bubbles obscure visualization, simethicone solution should be infused into the lumen to dissolve the bubbles. If a segment cannot be cleaned because of residual particulate matter, a problem most commonly found in the cecum and right colon, sometimes repositioning the patient will shift the pool of fluid to the opposite wall and expose the surface that was previously poorly seen.⁵⁷ Any collapsed areas should be distended adequately to efface folds that might obscure

lesions. A systematic examination requires looking at the proximal and distal surfaces of all haustral folds, usually done by making a circular motion around each sulcus. To see everything, it is often necessary to travel through a section of bowel several times. A second look has been shown to improve adenoma detection rate in the ascending colon either with a forward or retroflexed view.³² At areas of angulation, especially the flexures, some surfaces may lie outside the scope's field of vision, in which case readvancing the scope may alter the scope's position in the lumen and redirect the tip favorably.

Exam of the cecum should include a deliberate identification of all three segments of the cap (the triangular area between the crow's feet folds, which harbors the appendix, and the two areas on either side). The area behind the ileocecal valve is the most difficult to visualize completely and may require several passes to see thoroughly.

Inspection of the rectum should include a retroflexed view of the distal rectum and anorectal junction, a blind spot from the forward view. This may not be safe to do in a narrower lumen or when there is active inflammation.

For patients undergoing evaluation for intestinal bleeding, if active bleeding or adherent clots are not found, the focus shifts to identifying lesions that may have bled, including neoplasms, ulcers, inflammation, ischemic necrosis, hemorrhoids, AVMs, and diverticulosis. The terminal ileum should be examined for possible IBD. An adherent clot or visible vessel adds evidence that the exact cause of bleeding has been identified. If old blood or reasonably fresh blood is present in the lumen, it may help to identify which is the most proximal segment in which blood is seen. Although reflux movement of blood may make this data inaccurate, it can nonetheless offer some clue to the region where bleeding occurred.

For patients being evaluated for diarrhea, the most important finding is inflammatory mucosal changes of erythema, loss of vascular pattern, and ulceration. Entry into the terminal ileum should be done to look for IBD or carcinoid. Biopsies should be done of any abnormal areas and randomly if the mucosa appears normal to search for microscopic colitis. Additional biopsies for viral culture may be appropriate in immunosuppressed patients.

IMPROVING DETECTION OF LESIONS

Colonoscopy has successfully reduced the overall rate of colon cancer. But the development of interval cancers between scheduled colonoscopies⁶⁶ and the failure of colonoscopy to reduce cancer in the right colon³⁵ reflect the imperfection of colonoscopy. The miss rate of adenomas is reported as high as 22%, although most of these are smaller lesions and only 2% of lesions larger than 1 cm are missed.³⁴ A higher rate of adenoma detection is clearly related to successful cancer prevention,³⁶ so all efforts should be made to maximize detection of lesions.

In addition to using the techniques described above, recruiting the eyes of multiple observers can increase the

rate of polyp detection,³⁷ so when possible, the nurse or technician in the room should watch the screen as well.

Technological advances can help as well. High-definition cameras and monitors are now standard and have improved identification of flat and smaller lesions. Two newer technologies currently available are narrow band imaging (NBI) and chromoendoscopy. The illumination source for NBI is confined to two specific wavelengths, 415 and 540 nm, which accentuates blood vessels and improves the sensitivity and specificity of differentiating non-neoplastic from neoplastic mucosal lesions.³⁸ With this technique, an adenomatous polyp may stand out darker against normal mucosa. Some physicians use NBI as their principal light for screening during withdrawal, but if the colon has any residual fluid or solid material, these become particularly distracting and may actually detract from recognizing polyps. Chromoendoscopy involves applying a temporary topical stain to the mucosa, such as methylene blue or indigo carmine, which emphasizes subtle changes in the mucosal texture. This is most commonly used for screening patients with IBD.⁵⁶ Emerging technologies are confocal laser endomicroscopy and endocytoscopy, which provide real-time evaluation at cellular and subcellular levels, a technology that may help identify dysplasia in ulcerative colitis.

Technologies available to broaden the visual field of the colonoscope can also improve detection of lesions. A simple cuff placed over the end of the scope to flatten haustral folds can improve detection of lesions.³³ The Third Eye attachment provides a retroflexed view from the tip of the scope, allowing for easier detection of lesions on the proximal side of haustral folds.³⁹ The Fuse Full Spectrum system has three cameras on the tip of the scope (a standard forward view and two lateral lenses) projecting images onto three adjacent screens, increasing the field of view from 170° to 330°. Studies show this technology improves adenoma detection by an astonishing 67%.⁴⁰

DETERMINING LOCATION IN THE COLON

It is important to document the most proximal portion of bowel that is reached during the procedure. In most procedures, this will be the cecum, which should be identified by at least two of its landmarks, including the appendiceal orifice (a semicircular indentation often surrounded by a rosette of circular folds), the ileocecal valve (thickening of the first cecal fold or a visible opening with ileal mucosa and villi), and the classic "crow's foot" pattern of haustral folds.⁵⁴ The endoscopist should be aware that diverticula can be mistaken for the appendiceal orifice, especially when combined with a difficult angle or flexure that seems to be a blind end. Observing the light transilluminating the abdominal wall in the right lower quadrant and/or observing indentation from external pressure can be helpful as well.

Determining the location of the tip of the scope elsewhere in the colon is more difficult because there are few identifying features, other than the rectal vault and anorectal

junction.⁵³ The internal appearance of the lumen can sometimes help—a triangular lumen is typical of the transverse colon and sometimes the descending colon, and acute angles may suggest a flexure. The length of scope that has been inserted is one useful measurement, but it is often inaccurate because of looping and redundancy; it may be more reliable during withdrawal.

Determining location is important for identifying the site of a neoplasm or other pathology. Because identification techniques leave some uncertainty, it is helpful to record both the distance from the anus and the estimated segment of its location. Observing indentation of the colon wall from an external finger poke can also help. If it is important to provide a means of reidentifying the exact site of a lesion, such as a large adenoma needing future endoscopic monitoring or a malignant lesion requiring surgery, a tattoo can be applied to the adjacent mucosa, using two or three submucosal injections of 1 mL of India ink, which effectively stains both the mucosal and serosal surfaces.⁵⁵ Clips can also be applied to the mucosa for radiographic localization, although they remain attached only temporarily.

THERAPEUTIC INTERVENTIONS DURING DIAGNOSTIC COLONOSCOPY

When diagnostic colonoscopy detects a lesion, sampling is usually done with either a biopsy forceps or a cytology brush. Polyps up to 10 mm in size should be routinely removed, either with a biopsy forceps or a snare, with or without cautery, and in most circumstances, polyps up to 20 mm can be removed easily and safely. A bleeding lesion may be treated with epinephrine injection, cautery, or clipping. A stricture may need balloon dilation to permit further advancement of the scope. Further discussion of these procedures is found in subsequent chapters.

Although a careful evaluation of the lumen is not the primary goal during intubation, if a small polyp is identified on the way in, it is often best to remove it at that time, since it can be hard to relocate during withdrawal. Larger lesions are usually removed during the withdrawal phase.

DOCUMENTATION

Completion of the procedure includes detailed documentation, which should include appropriate identification data, indication for the procedure, sedation used, extent of the exam, quality of the preparation, any complications, discussion of the procedure, and details of the findings (location, size, characteristics of any abnormalities), plans for follow-up of pathology results, instructions for changes in medications, follow-up with physicians, and recommended interval to the next screening procedure. Photographs of abnormalities found are commonly included in the report and should be properly labeled. Photographing the appendiceal orifice

as documentation of reaching the cecum has been shown to improve cancer prevention.⁵²

POSTPROCEDURE CARE

The patient should be monitored until his or her mental status and vital signs have returned to normal and the patient can ambulate safely. They should be instructed about proper postprocedure care, including diet, activity restrictions, and resumption of medications (with special attention to anticoagulants). It is ideal to inform them also of the results of the procedure, how pathology results will be communicated to them, what follow-up plans are advised, and the proposed interval until the next screening procedure. When appropriate, it is good to compliment the patient about having done a good job preparing for the procedure. As patients frequently are still affected by sedation and may not recall details of the discussion, a printed set of instructions that includes the above elements should be given to them as well.

COMPLICATIONS

The rate of serious complications for diagnostic colonoscopy (0.28%) includes those related to preparation, sedation, and the procedure.⁴¹ Complications of the preparation include nausea, vomiting, bloating, pain, dehydration, renal failure, hypokalemia, atrial fibrillation, syncope, and hypoglycemia. Complications from sedation include hypotension, hypoventilation, arrhythmia, allergic reactions, nausea, and intravenous site inflammation or thrombosis. Complications from the procedure include hemorrhage, perforation, mucosal trauma, barotrauma, and bradycardia from vagal stimulation, and postoperative pain and nausea and gas retention. Death is a rare complication of diagnostic colonoscopy but is reported as high as 1/35,000 procedures.⁴² If interventions are added to a diagnostic procedure, this adds additional risk. The complication rates for an institution or endoscopy center should be available to share with patients and to use when informed consent is obtained. An individual operator's personal experience should be known as well, although this may be more subject to variations depending on patient mix and the frequency with which the individual undertakes higher-risk interventions.

QUALITY MEASURES

Measures of the quality of colonoscopy should address efficacy, safety, and comfort.⁴³ The quality of a physician's skill and that of the whole endoscopy suite should both be monitored routinely. A common parameter of efficacy is the adenoma detection rate (ADR), calculated as the percentage of healthy normal-risk patients in whom one or more adenomas is detected; an ADR of greater than 25% is generally

accepted as good quality. A second measure of efficacy is the cecal intubation rate, the percentage of time the cecum is entered in those patients with a normal colon; a good quality endoscopist should reach the cecum more than 95% of the time. A surrogate measure for success of adenoma detection is the withdrawal time, measured as the time to withdraw the scope from the cecum to the anus; a time greater than 6 minutes is considered appropriate, although the results of studies are mixed as to whether longer withdrawal times correlate with higher ADRs.^{50,51}

Safety is usually measured by tracking complication rates. This can be affected by patient selection and type of procedure being done (EMR carries higher risk, for example), so complication rates should be compared to national benchmarks and should be trended over time, which can help detect significant aberrations from normal. Patient comfort and satisfaction are not commonly tracked as a quality measure, but questionnaires can be used if this issue becomes a concern. Other quality measures commonly used relate to adherence to procedural standards, such as appropriate documentation, appropriate indications, consent, or number of surveillance biopsies taken during IBD screening.

ALTERNATIVE SCREENING OPTIONS

For colorectal cancer screening, offering patients alternatives rather than just colonoscopy may increase patient participation in colon cancer prevention programs.⁴⁹ There are several tests that provide indirect evidence of the presence of neoplasms, which if positive would lead to colonoscopy for definitive evaluation. Fecal occult blood testing with flexible sigmoidoscopy have been shown to reduce the risk of colon cancer.⁴⁸ Fecal immunochemical testing (FIT) and a DNA assay are combined in Cologuard, which requires only a stool sample and which has been shown to detect cancers and significant large polyps almost as well as colonoscopy, although it is poorer at finding smaller lesions and has a significant rate of false positives.⁴⁶ CT colonography (“virtual colonography”) is as effective as colonoscopy at detecting large polyps and malignant lesions, although it may miss flat lesions and polyps under 1 cm in size.⁴⁴ Whether CT colonography or Cologuard will prove successful at reducing colon cancer has yet to be determined.

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Lower endoscopy therapeutic dilation and stenting

DAVID E. BECK

INTRODUCTION

Colonic strictures result from inflammatory bowel disease (Crohn disease and ulcerative colitis), anastomotic problems, ischemia, malignancy, radiation injury, nonsteroidal anti-inflammatory drugs, and the consequences of diverticulitis.^{1,2} The location and degree of the stricture often determine the significance of symptoms. High-grade strictures may lead to a complete obstruction and a surgical emergency. Colonic obstruction is a common clinical problem in the United States, and the majority are due to malignant processes. Approximately 8%–29% of patients with colorectal cancer initially present with symptoms of partial or complete bowel obstruction, most of which are left sided and either Stage III or IV.^{2,3} There are several options to manage patients with large bowel obstruction. Traditionally, patients were resuscitated, evaluated with a contrast study such as a water-soluble enema (**Figure 16.1**), computed tomography scan, or colonoscopy and then taken to surgery. Surgical options for right-sided lesions usually involved a segmental resection and an ileocolic anastomosis or ileostomy depending on the status of the bowel and patient as well as the experience of the surgeon. Management of left-sided lesions traditionally varied: a segmental resection and colostomy, a subtotal colectomy, and ileorectal anastomosis or ileostomy. These emergency procedures had an associated mortality of 10%–30% and a morbidity of 10%–36%.^{2–4} Due to their age and comorbidities, many of the patients receiving ostomies did not have their stomas closed, and the time spent recovering from therapy or associated with their morbidity or complications from surgery often delayed or prevented chemotherapy and radiotherapy. Quality of life and the cost of ostomy supplies has also been an issue. These limitations encouraged development of other options such as endoscopic balloon dilation and self-expanding intraluminal stenting. This chapter

reviews the indications, techniques, and published results of endoscopic colonic balloon dilation and intraluminal stents for colonic obstructions.

PATIENT SELECTION AND INDICATIONS

Proper patient selection is important to obtain a successful outcome. The history, examination, and diagnostic



Figure 16.1 Contrast enema demonstrating an obstruction colonic lesion. (Courtesy of Ochsner Clinic Foundation.)

studies will often suggest an etiology and provide information on characteristics of the stricture, which are predictive. Predictors of a successful outcome include narrow stenosis (<10 mm) and short strictures (<4 cm) that are accessible.¹ Anastomotic strictures do better with dilation, while malignancies respond better with intraluminal stents. Additional poor predictors are numerous strictures, complete obstruction, associated fistulas within the stricture, and active inflammation at or around the stricture. Finally, the patient's lesion must be accessible to an endoscope and not have an absolute indication for a laparotomy (e.g., perforation).

Balloon dilatation may resolve an anastomotic or inflammatory stricture, but repeat treatments are often necessary. Intraluminal stenting can be used for palliation or as a bridge to surgery (converting an emergency procedure to an elective one). The use of stents for nonmalignant obstruction has been limited. Since their introduction in 1991, colonic stents have become an important method of palliation for obstruction in colorectal cancer patients, especially those with unresectable metastatic disease.⁵ These self-expanding metallic stents can potentially dilate the lumen to a near-normal diameter, providing quick relief of symptoms and, in some cases, allowing endoscopic or radiologic assessment of the proximal colon. Stents can be placed in patients using minimal sedation, without need for prior endoscopic dilation and a low risk of complications such as perforation or tumor fracture. Moreover, these stents can be placed across relatively long lesions by overlapping stents in a “stent-within-stent” fashion. Most patients with benign strictures are better managed with dilatation or traditional operative techniques, as the morbidity associated with stents in this patient group has been prohibitive. However, increasing experience with stents used as a bridge to surgery in selected patients with benign strictures is accumulating.

TECHNIQUE

Endoscopic balloon dilation

The endoscope is passed via the anus until the stricture is encountered (**Figure 16.2**). Fluoroscopic assistance is rarely needed. A guidewire or balloon catheter is passed via the accessory port of the endoscope through the stricture under direct visualization (**Figure 16.3**). The balloon catheter is advanced over the guidewire or to the midpoint of the stricture and inflated with saline using a pressure- or volume-controlled handle. It is important to keep the balloon centered on the stricture during inflation to prevent it slipping out of the stricture. Inflating the balloon slowly and using longer balloons help to minimize the risk of migration.¹ After removal of the balloon, the dilated stricture is usually examined endoscopically. Several endoscopically guided balloons are available. For colonic use, the balloons range in size from 6 to 20 mm diameter.



Figure 16.2 Colonoscopic view of obstructing lesion. (Courtesy of Ochsner Clinic Foundation.)

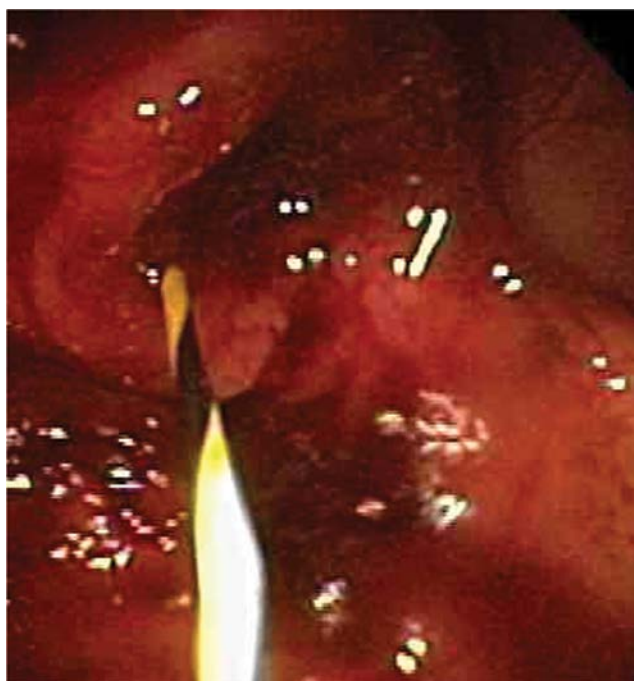


Figure 16.3 Insertion of a through-the-scope (TTS) guidewire through the obstruction. (Courtesy of Ochsner Clinic Foundation.)

Intraluminal stents

A number of intraluminal stents are currently available (**Table 16.1**). They are composed of stainless steel or alloys. Nitinol is an alloy of nickel and titanium, which has increased flexibility that is helpful for stenting sharply angulated regions at the cost of lesser radial force relative to stents made from other metals. Elgiloy is an alloy of cobalt, nickel, and chromium and is corrosion resistant and capable of generating high radial

Table 16.1 Available stents

Stent	Manufacturer	Composition	Deployment	Size (diameter/ length)
Wallflex	Boston Scientific	Elgiloy	TTS	27–30 mm 60–120 mm
Wallstent	Boston Scientific	Stainless steel	TTS	20 and 22 mm 60 and 90 mm
Evolution Colonic Controlled-Release	Cook Medical		TTS	25 mm 60, 80, 100 mm
Evolution Duodenal Uncovered Controlled Release	Cook Medical		TTS	22 mm 60, 90, 120 mm
Z-stent	Cook Medical	Stainless steel	OTW	25 mm 40–120 mm
Ultraflex Precision	Boston Scientific	Nitinol	OTW	30/25 mm 57–117 mm

Note: OTW, over the wire; TTS, through the scope.

forces. Stents are produced in coated and uncoated versions. Coated stents may have lower rates of tissue ingrowth, which may produce a longer patency, but they have a higher rate of migration. There is some evidence that they may aid in fistula closure.^{1,6} Currently, only uncoated stents are approved for use in the colon. Colonic stents range in predeployment diameter from 10 to 30 F and postdeployment diameter of 20–35 mm, and 40–120 mm in length. Most have a proximal and/or distal flare to prevent migration. The stents are generally packaged in compressed form and constrained on a delivery device.

A stent can be deployed through the scope (TTS) with or without a guidewire or passed under fluoroscopic control over an endoscopically or fluoroscopically placed guidewire. Enteral stents may be uncovered or covered (referring to whether the meshwork of the stent is bare-wire or has a covering to decrease tissue ingrowth into the stent).⁶ The author's preference is an Enteral Wallflex 120 mm in length (Boston Scientific). TTS stents are easier to place through proximal or angulated lesions.

The following is the technique used by the author. Patients are taken to the endoscopy unit and placed on a fluoroscopically capable table. After placement of monitors and nasal oxygen, the patient is placed into a left lateral position and sedated. A colonoscope is inserted and advanced to the obstructing lesion. Fluoroscopy is used to observe the lesion location, and the patient's position is altered to obtain the best fluoroscopic view. Intraluminal contrast may assist in this localization and positioning. If the lumen appears tight, a flexible guidewire is inserted through the working port of the colonoscope, and under direct vision it is gently passed across the obstruction (**Figure 16.3**). If the lumen is not so tight, the stent may be passed across the lesion. Fluoroscopy confirms that the wire or catheter has passed through the lesion. If a guidewire was used, a TTS stent is then passed through the scope over the guidewire and passed across the lesion (**Figure 16.4**). Radiopaque markers of the stent help position it across the obstructing lesion. Under fluoroscopic visualization, the stent is deployed slowly. Some repositioning is possible prior to complete stent

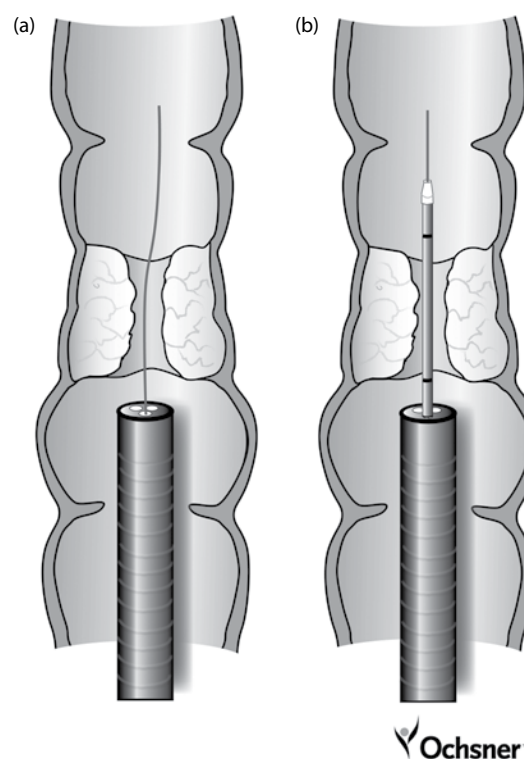


Figure 16.4 (a) Guidewire passed across the stricture. (b) Undeployed stent is passed through the stricture. Black markers indicate radiopaque markers. (Courtesy of Ochsner Clinic Foundation.)

deployment. Optimally the configuration of the deployed stent will have a flare proximal and distal to the stricture with a narrowed neck at the stricture. Successful deployment is often associated with a rush of gas or colonic contents through the deployed stent. Following successful deployment, a contract study or plain film will confirm appropriate deployment (**Figure 16.5**). If the stricture is long or the stent does not have adequate extension across the stenosis, a second stent can be

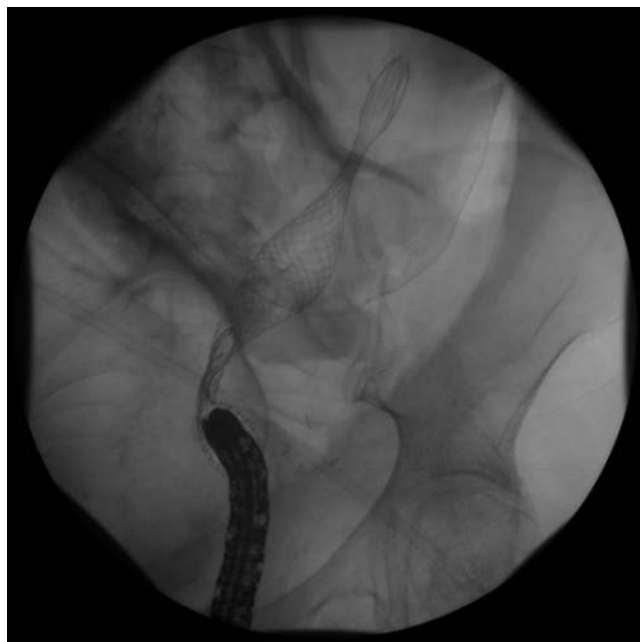


Figure 16.5 X-ray of stent in place. (Courtesy of Ochsner Clinic Foundation.)

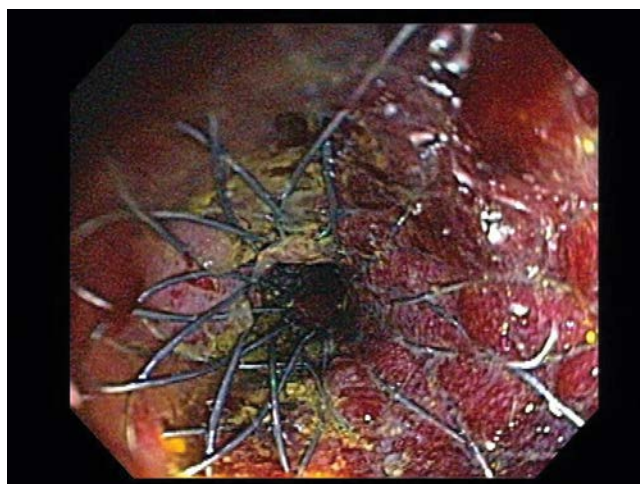


Figure 16.6 Endoscopic view of deployed stent. (Courtesy of Ochsner Clinic Foundation.)

placed overlapping a portion of the initial stent. Attempting to pass the colonoscope through the stent after deployment should be avoided as the metal edges of the stent can damage the colonoscope (**Figure 16.6**).

RESULTS

Stenting has been more successful in shorter, distal lesions and with colonic primaries.⁷ Technical failure is usually due to the inability to pass a guidewire or stent catheter across the obstruction, usually due to angulation of the tumor. Clinical

failure is usually defined as failure to relieve the obstruction or the occurrence of a major complication. The published experience on management of colonic strictures and obstruction is derived from case series, small comparative trials, and retrospective studies. To overcome these limitations, a number of systematic reviews have been performed.

MALIGNANT STRICTURES

Watt and colleagues in 2007 reviewed 88 articles (15 of which were comparative) and found a technical success of 96% (range 66%–100%) and a clinical success of 92% (range 46%–100%).⁸ The hospital stay was shorter with stents in most studies. The median rate of reintervention was 20% (range 0%–100%); the median stent migration rate was 11% (range 0%–50%); and the median perforation rate was 4.5% (range 0%–83%).

A Cochrane meta-analysis in 2011 of five randomized trials of 207 patients compared stents with surgery.⁹ Stent placement was successful in 86% of patients, with a perforation rate of 6%, a migration rate of 2%, and an obstruction rate of 2%. The average time of clinical relief of obstruction was significantly lower with stent placement compared with emergency surgery. There was no difference with regard to 30-day mortality or complication rates.

A recent meta-analysis of 11 studies and 1,136 patients compared the long-term outcome of stents as a bridge to surgery (38%) to emergency surgery (62%).¹⁰ The overall and disease-free survival were similar between the group, suggesting that stenting is a promising alternative for malignant large bowel obstruction.

NONMALIGNANT STRICTURES

Intestinal strictures result from a number of conditions. Benign conditions such as inflammation (inflammatory bowel disease) or postoperative anastomosis often respond to dilation. In 1989, Aston et al. reported their experience with nine patients who underwent balloon dilatation of colon and rectal anastomotic strictures. Six of the nine strictures resolved after a single dilatation.¹¹ Park and colleagues retrospectively reviewed 43 consecutive patients with benign strictures.¹² Twenty-nine had balloon dilatation, seven had stents, and seven had both procedures. The clinical success was similar (balloon 89.1% and stent 87.5%). Reobstruction rates were similar (balloon 54.4% and stent 57.1%, but the duration of patency was longer for the balloon 65.5 months). The authors felt that endoscopic balloon dilatation was safe and effective as an initial treatment.

Small and colleagues described 23 patients who underwent intraluminal stent placement for benign colonic strictures.¹³ Technical success was obtained in 95% of the patients, but complications occurred in 38%. Eighty-seven percent of these complications occurred after 7 days of placement. The authors felt that intraluminal stents were useful as a bridge to surgery, which should be performed within 7 days if possible.

SUMMARY

The published data suggest that in experienced centers, an initial attempt at stent placement by an experienced multidisciplinary team is the preferred option for malignant obstruction. Endoscopic procedures can serve as a bridge to surgery in potentially curable, fit patients and provide effective and durable palliation for selected patients with malignant obstruction. Dilatation may be used in selective benign strictures, while stenting may provide a bridge to surgery.

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Transanal endoscopic microsurgery

JOHN H. MARKS AND JEAN F. SALEM

INTRODUCTION

Transanal endoscopic microsurgery (TEM) is a minimally invasive technique that was first described by Buess in 1983. It was originally developed for the treatment of large villous adenomas, but its indications were then expanded to excision of rectal cancers after treatment with neoadjuvant therapy. This procedure is performed transanally with specially designed microsurgical instruments. This surgical approach is both a single-port surgery and a natural orifice transluminal endoscopic surgery (NOTES).

There has been ongoing interest in TEM due to an increase in sphincter preservation, better functional outcomes, and reduced short-term morbidity and mortality.^{1,2}

TEM has emerged as a safe and effective method and has become the procedure of choice for the treatment of different types of rectal lesions.

INDICATIONS

TEM was initially used for benign adenomas not amenable to endoscopic resection and for invasive cancers in patients with multiple comorbidities who were considered to be high risk for radical surgery. However, as experience with TEM has grown, its indications were expanded. It became the procedure of choice for local excision of selected “low-risk” T1 rectal cancers with long-term survival similar to that achieved after total mesorectal excision (TME).³ It can also be used after chemoradiation in T2 or T3 lesions that have regressed into the bowel wall.^{4,5} The cancer should be less than 3 cm in size and mobile (**Figure 17.1**).

EQUIPMENT

- *Operating rectoscope*: 4 cm in diameter and either 12 cm or 20 cm in length with a beveled or straight-faced end.

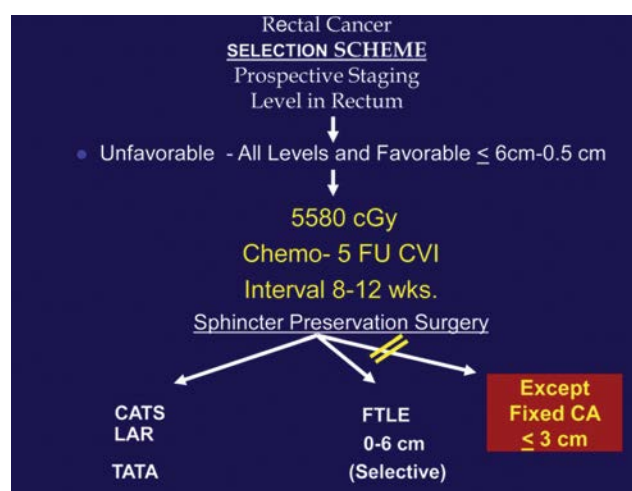


Figure 17.1 Rectal cancer management algorithm.

The rectoscope is attached to the operating table with a Martin arm. There are four pieces of tubing that should be attached to their respective ports. They are used for continuous insufflation, suction, irrigation, and light source. The faceplate has four ports sealed by capped rubber sleeves through which the optical stereoscope, suction, and two long-shafted instruments are inserted (**Figure 17.2a and b**).

- *Stereoscope*: used to visualize the field through a monocular scope connected to a screen or through a binocular eyepiece. The operative field is magnified up to sixfold (**Figure 17.3a and b**).
- *Long-handled instruments*: all operating instruments are 5 mm in diameter and include graspers, scissors, monopolar cautery hook, needle driver, and clip applicator. The graspers are either straight or more commonly used angled at the tip (**Figure 17.4a–c**).

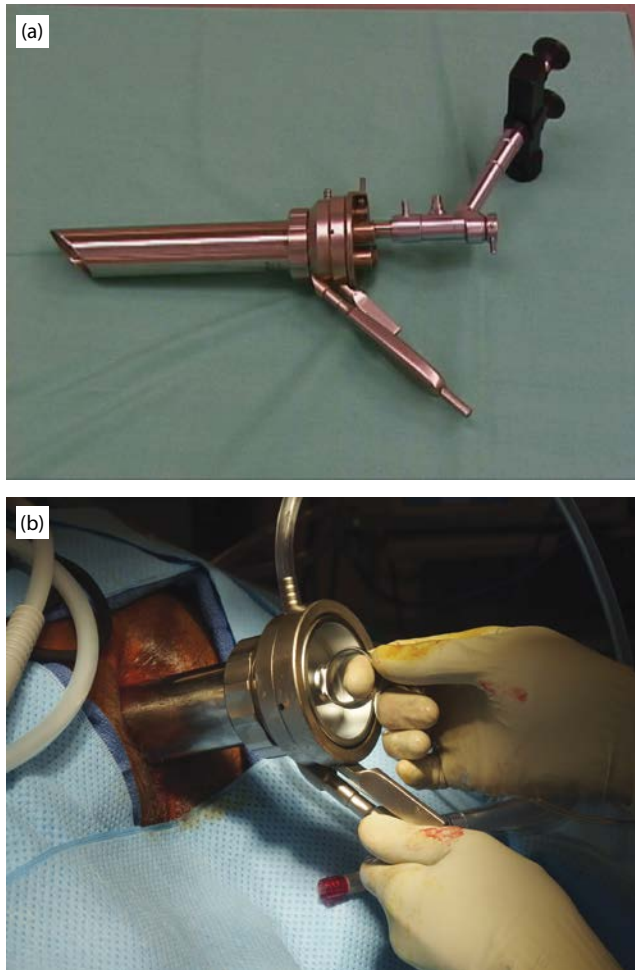


Figure 17.2 (a) Rectoscope. (b) Insertion of the TEM rectoscope. After gentle dilation of the anus, the rectoscope is inserted with an obturator in place for an atraumatic entry.

- **Endosurgical unit:** provides light source, carbon dioxide (CO₂) insufflation, suction, irrigation, and continuous monitoring of intrarectal pressure. Simultaneously, an integrated roller pump provides constant low-volume suction at the same rate as the gas insufflation. This permits adjustable effective suction that does not collapse the lumen.

OPERATIVE TECHNIQUE

All patients receive standard mechanical bowel preparation the day before surgery as well as preoperative antibiotics. The positioning of the patient is essential in TEM; it depends on the tumor location. In general, the patient is positioned so that the tumor is in the dependent position during the procedure (6 o'clock). This is essential as the optics reside in the upper portion of the operating proctoscope, limiting the reach of the instruments to the bottom 180°–210° of the lumen. Patients with posterior lesions are placed in the modified lithotomy position. Patients with anterior lesions

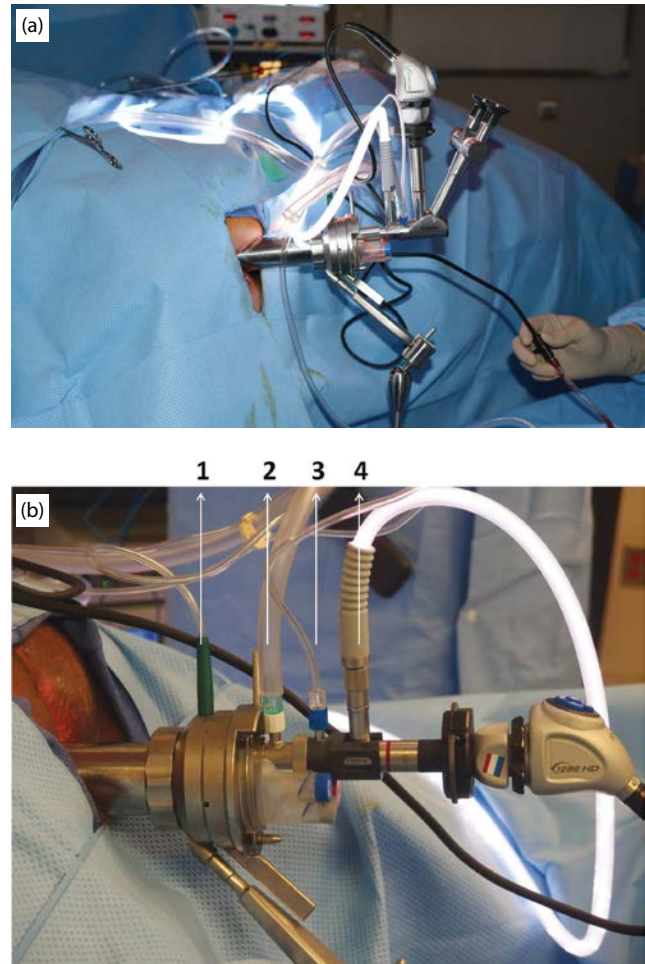


Figure 17.3 (a) Finalized assembly of the TEM stereoscope. (b) Four ports are used for suction (1), continuous insufflation (2), irrigation (3), and for the light source (4).

are placed in the prone position (**Figure 17.5**). Patients with left or right lateral lesions are placed in the left or right decubitus position, respectfully.

The operation starts by a gentle dilatation of the anus and insertion of the rectoscope. The obturator is then removed, and the working faceplate is secured. At this point, the TEM rectoscope is functioning as a large rigid proctoscope. The lesion is positioned in the center of view at the 6 o'clock position. The rectoscope is then fixed to the operating table using a Martin arm. The stereoscope is then introduced, all the connections are attached to the rectoscope, and insufflation is started (**Figure 17.6a and b**).

Dissection is started by scoring the lesion circumferentially using electrocautery (**Figure 17.7**). This is important to delineate the lesion and get a known margin. A 0.5 cm margin is appropriate for benign lesions and 1 cm for cancers. Using a grasper with the left hand, the mucosa is lifted, and a full-thickness excision is performed using electrocautery. One should make sure to reach the perirectal fat. Often, a layer of adipose tissue is found below the submucosa before entering the muscularis propria. This

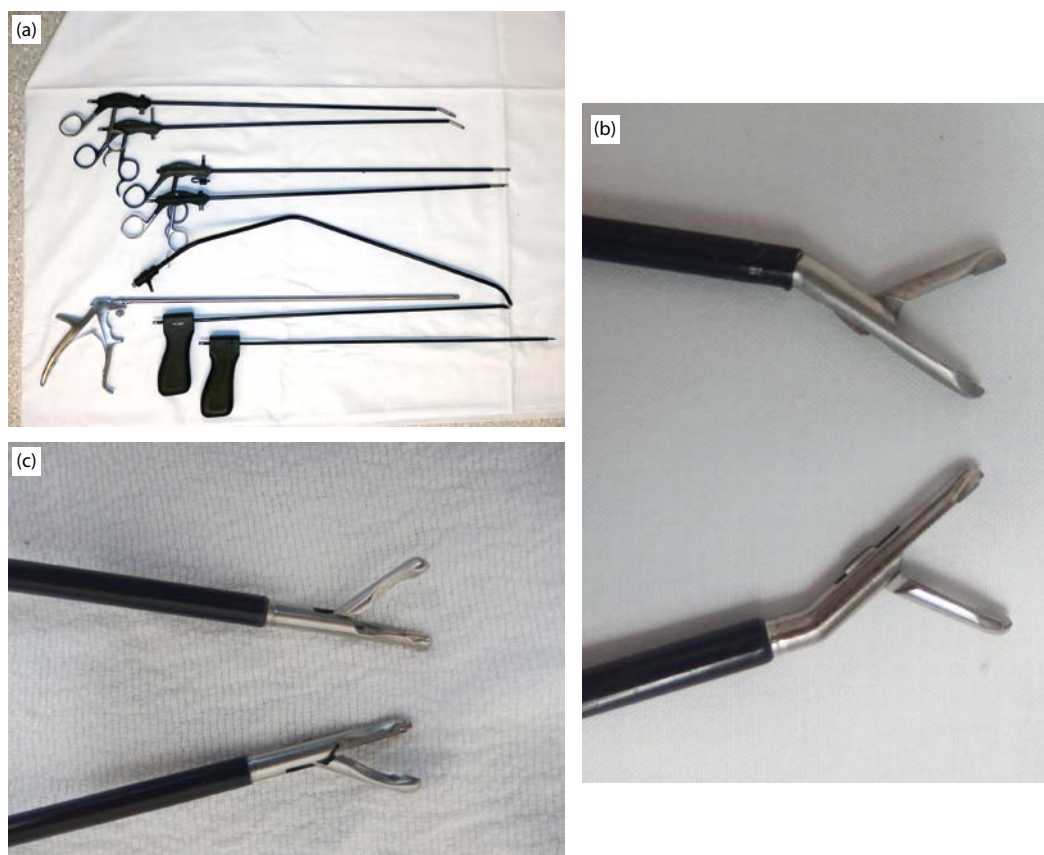


Figure 17.4 (a) Important handheld TEM instruments. From top to bottom: curved monopolar grasping forceps for left and right hands, straight monopolar grasping forceps for left and right hands, suction tube, suture clip forceps, articulated monopolar knife, and straight monopolar knife. (b) Close-up of curved forceps. (c) Close-up of straight forceps.

should not be mistaken with the perirectal fat. Ideally, the area around the lesion is connected circumferentially, and then the base of the lesion is excised (**Figure 17.8a and b**). A marking suture is placed at the inferior border of the specimen prior to removal to ensure proper orientation of the specimen (**Figure 17.9**). The insufflation is then turned off, and the specimen is grasped and pulled into the operating rectoscope. The faceplate is removed, and the specimen



Figure 17.5 Prone position: ideal for patients with anteriorly located lesions.

is delivered. In order to reduce the risk of tumor implantation and local recurrence, the defect, the faceplate, and the instruments are washed and irrigated with dilute Betadine. The defect is closed in a running, full-thickness fashion with a 2-0 PDS suture. This step is particularly challenging because there is no space for left and right or up and down movements. Instruments should always remain in parallel and can only be moved in and out. The suture is advanced by inserting the needle driver into the lumen of the rectum and pulled out in a pistonlike motion. The closure progresses in a right-to-left fashion. Knot tying using TEM equipment is also very difficult and is instead achieved using silver clips, which are secured onto the suture. Once closure is complete, any slack in the suture line can be fixed by gently pulling up on one end of the suture and applying another clip to tighten it (**Figure 17.10**).

TECHNICAL VARIATIONS

1. Submucosal excision: this can be done for adenomas only
2. Intramuscular
3. Full thickness through the muscularis propria
4. Partial-thickness mesorectum
5. TME-level mesorectal excision

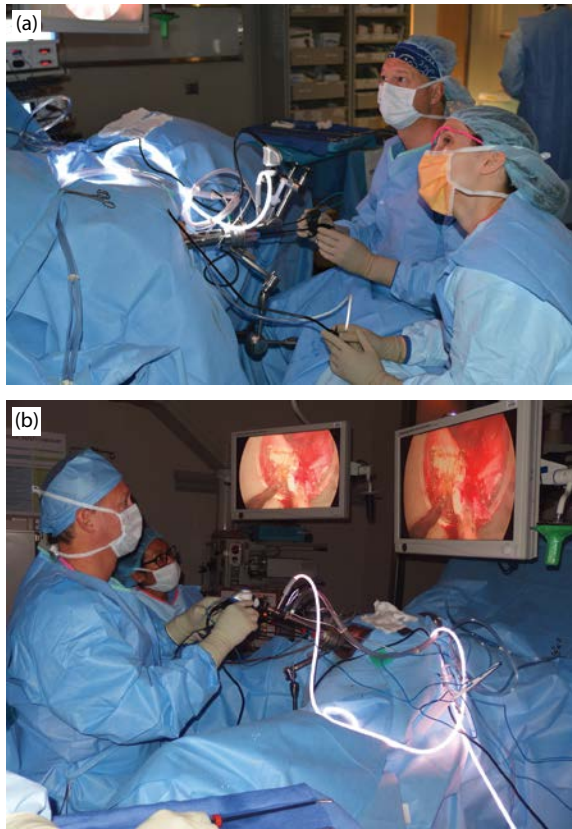


Figure 17.6 (a) Surgical team setup. The surgeon is in a seated position in between the patient's legs, with the assistant positioned to his or her left side. (b) The monitors are placed in front of the surgeon. The operating rectoscope is fixed to the operating table with a Martin arm for stability.



Figure 17.7 The lesion is scored circumferentially.

The risk of entry into the peritoneal cavity is increased in high anteriorly based lesions. These lesions are best addressed with a low anterior resection. However, in very experienced hands, entry into the peritoneal cavity is safe and does not increase the risk of carcinomatosis or sepsis.⁶ Closure is preferably performed in two layers.

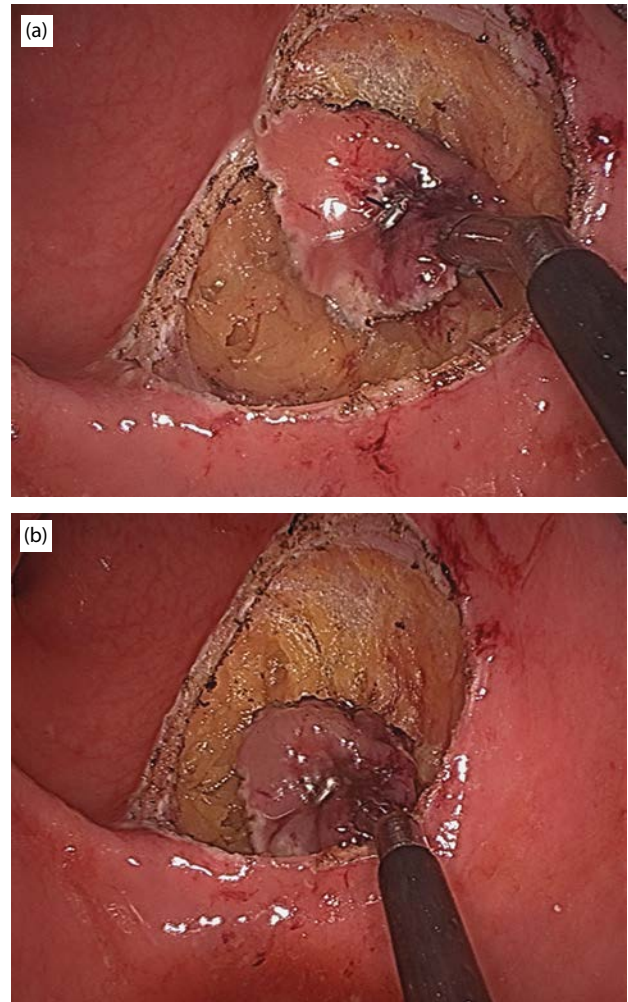


Figure 17.8 (a and b) The lesion is dissected circumferentially, and then the base of the lesion is excised.



Figure 17.9 Placement of a marking suture. Prior to complete excision, a marking suture is placed in the distal margin of the target lesion for orientation.

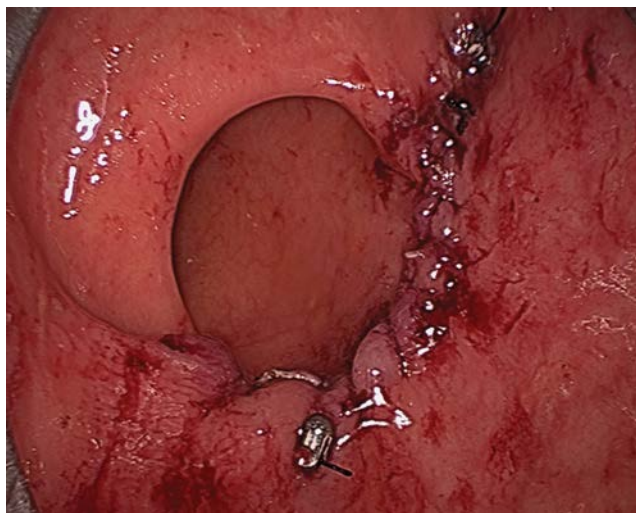


Figure 17.10 The defect is closed in a running, full-thickness fashion with a 2-0 Polydioxanone (PDS) suture.

OUTCOMES

One of the major benefits of the TEM procedure is the decrease in postoperative morbidities and mortalities compared to TME.²

From an oncological standpoint, TEM and radical surgery for T1 cancers have similar rates of recurrence and survival.⁴ For T2 rectal cancers after neoadjuvant therapy, a prospective randomized study comparing TEM and TME

showed a local recurrence rate of 5.7% in the TEM group and 2.8% in the TME group.⁵

From a functional standpoint, satisfaction with fecal continence is generally high with TEM. For very low early rectal cancers, TEM can spare the patients from having a permanent colostomy while preserving an appropriate sphincter function.⁷

CONCLUSION

TEM is effective and safe for treatment of benign lesions as well as select invasive cancers of the rectum. It allows the surgeon to tackle lesions too difficult to approach with conventional transanal excision with improved immediate endpoints (margin positivity and specimen fragmentation) and lower long-term recurrence rates. Compared to radical excision of the rectum, TEM has less morbidity, faster recovery, and better function with similar oncologic outcomes if used selectively.

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Transanal minimally invasive surgery

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INTRODUCTION

Following the popularization of colorectal cancer screening, the incidence of large rectal polyps and early stage cancer is increasing.¹ Furthermore, due to a myriad of factors including suboptimal functional outcomes following oncological proctectomy, an aging population, stoma aversion, and improving response rates following neoadjuvant chemoradiation, local excision of early stage rectal cancer is increasingly being requested by patients and utilized in clinical practice.² Until recently, the modalities available to surgeons for the local excision of both large rectal polyps and early stage cancers include traditional transanal excision (TAE), advanced colonoscopic techniques, and transanal endoscopic microsurgery (TEM).

TEM (more recently modified to transanal endoscopic operation [TEO]), first described in 1984 by Gerhard Bues,³ represents the intraluminal excision of a rectal lesion using a rigid resectoscope. This surgical modality maintains a stable pneumorectum and allows either high-definition or binocular optical visualization of the target site combined with precise instrumentation for tissue tensioning, dissection, resection, and mucosal re-apposition. Meta-analyses of TEM for benign and malignant tumors of the rectum show significant advantages over alternative techniques. When compared to conventional TAE, TEM provides a superior quality resection, with higher rates of negative microscopic margins, reduced rates of specimen fragmentation, and lesion recurrence but with equivalent postoperative complications.⁴ When compared to advanced colonoscopic techniques such as endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD), TEM remains superior with respect to lesion recurrence.^{5,6}

A perianal approach is of profound benefit in the setting of benign disease, in patients unfit for a traditional abdominal approach to the rectum, or for palliation for

rectal cancer in someone with incurable disease. Traditional surgical approaches to rectal cancer involve the removal of the tumor with all associated lymphovascular tissue. This allows for curative excision with prognostication by allowing for complete staging of disease. Proponents of local excision for early stage rectal cancer attest that some tumors have a low probability of lymph node involvement and that this small risk is offset by the avoidance of, the not insignificant, morbidity and mortality associated with traditional proctectomy.

Unfortunately, while TEM has been used for more than 30 years, its establishment in routine colorectal practice has been slow due to a steep learning curve⁷ and significant associated initial cost of the operating system.⁸ The aforementioned requirement for safe, oncologically sound, and cost-effective access modalities for the local excision of rectal lesions has led to evolution of transanal minimally invasive surgery (TAMIS). Single-incision, multiport laparoscopic devices that have facilitated a wide spectrum of abdominal procedures^{9,10} provided colorectal surgeons with the devices and technical skill set necessary to perform complex surgery, under magnification, in a confined space, while operating along a single axis. As crossover exists in instrument design and attained skill sets, it was realized that the techniques applied to single-incision surgery could be used for transanal rectal surgery. First described in 2010 in a series of six patients using a multichannel port positioned transanally, TAMIS was found to be a feasible alternative to TEM, providing its benefits at a fraction of the cost without specialized instrumentation.¹¹

INDICATIONS AND CONTRAINDICATIONS

The indications for TAMIS are similar to that of TEM/TEO and standard TAE. These include benign adenomas, neuroendocrine tumors less than 2 cm in diameter,

and well-differentiated T1 invasive carcinoma less than 3 cm.¹² There exists no agreed-upon limit to the size of rectal adenoma that can be resected, the primary concern being excess tissue removal leading to a narrowed lumen and rectal stenosis. We know, however, from the TEM literature that rectal stenosis following TEM excision is rare even for lesions greater than 5 cm provided the lesion is not circumferential.¹³

The 2013 American Society of Colon and Rectal Surgeons practice parameters for the management of rectal cancer state that local excision is an appropriate treatment modality for carefully selected T1 rectal cancers without high-risk features.¹² This important guidance has been supported by a recent analysis of Surveillance, Epidemiology, and End Results Program data, demonstrating that local excision of T1 rectal cancer does not affect cancer-specific survival when compared to radical surgery.¹⁴ Obviously the concern here is the potential undertreatment of T1 lesions that are node positive. However, an analysis of 205 T1 rectal cancers from the Swedish Rectal Cancer Registry demonstrated the overall rate of nodal metastasis was 12%.¹⁵ Interestingly, if no adverse features (lymphovascular invasion or poor differentiation) were present, the rate is 6%.¹⁵ A recent meta-analysis of 4,510 patients highlighted the risk factors for nodal metastasis in the setting of T1 rectal cancer to include submucosal invasion >1 mm (odds ratio [OR]: 3.87), lymphovascular invasion (OR: 4.81), poor differentiation (OR: 5.60), and tumor budding (OR: 7.74).¹⁶ If any of these risk factors are present on final pathology, radical proctectomy is recommended in fit patients due to the high risk of lymph node metastasis. Similarly, for rectal carcinoids >20 mm or with adverse features, radical surgery with mesorectal clearance should be offered to suitable patients.¹⁷

Due to undesirable rates of local recurrence, patients with T2 lesions should be recommended to undergo traditional total mesorectal excision. Following neoadjuvant therapy for a rectal cancer with complete pathological response, local excision may be considered within the confines of a clinical trial.¹⁸ Local excision with TAMIS may be considered in this scenario, however, as a less invasive but oncologically inferior alternative to radical excision in those patients with prohibitive comorbidities, or who refuse radical surgery or a permanent colostomy. Finally, in patients with metastatic disease, TAMIS may be utilized for potential palliation and symptom control.

There are no notable absolute contraindications for TAMIS. For very distal lesions within 2 cm of the dentate line, there is difficulty achieving an adequate seal using the TEM platform. TAMIS ports conversely are approximately 4 cm in length and “hook” into place on the anorectal ring, thus blocking access to the dentate line and distal rectal mucosa. However, TAMIS surgeons have overcome this through development of a hybrid technique where the dissection is initiated using a traditional anorectal retractor for 1–2 cm above the dentate line, prior to inserting the port and completing the excision

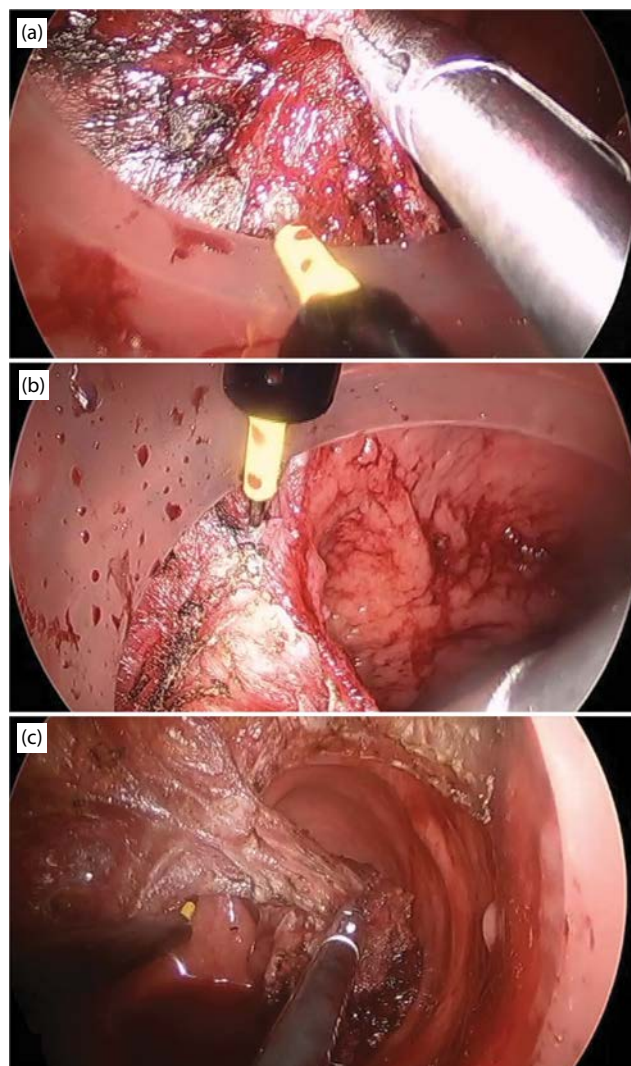


Figure 18.1 (a) Neoplasms that extend to the dentate line can be approached via a hybrid technique where the initial mucosal incision is performed with the aid of a traditional anorectal retractor followed by insertion of the port and the commencement of endoluminal dissection. A large near circumferential villous adenoma is approached utilizing this technique. (b) The distal mucosal margin is then able to be grasped and dissected cephalad both on the posterior, lateral, and anterior aspects. (c) Finally, the rectal wall at the proximal margin is divided and the specimen retrieved.

(Figure 18.1). Despite the notion by some that traditional TAE can be employed in these cases, there are major advantages to performing transanal endoscopic surgery in this scenario: specifically, lesions that start low but extend proximally, lesions that occupy more than a third of the lumen where frequent retractor changes are necessary, and in large bulky adenomas where major specimen fracture is sometimes inevitable. Caution must also apply in upper third rectal lesions situated anteriorly, as the peritoneum may be breached during resection. The majority of these peritoneal entries can be repaired using a transanal approach¹⁹; however,

laparoscopy may be required for confirmation of closure or assisted repair.²⁰ TEM's superiority over TAMIS is demonstrated primarily in its ability to reach more proximally into the distal sigmoid colon, although advanced TAMIS practitioners may still successfully resect more proximal lesions.²¹ The rigidity of the TEM rectoscope permits the rectum to be stented open, with reports of excision as high as 25 cm. To offset this imbalance, longer channel TAMIS ports have been experimented with, but noticeably offset many of the primary advantages of TAMIS.

The TAMIS platform may also be utilized for other pathologies including to repair rectourethral and complex Crohn fistulas, repair rectoceles, revise strictured low rectal anastomoses, repair anastomotic leaks,²² ligate bleeding vessels, and even extract foreign bodies from within the rectum.^{23,24} Furthermore, as transanal approaches to rectal surgery evolve, transanal TME (taTME) has come to the forefront as a new and exciting approach to performing minimally invasive proctectomy with sphincter preservation. TAMIS is rapidly becoming the preferred access modality^{25,26}; indeed, the first completely transanal TME reported was performed using TAMIS.²⁷

PREOPERATIVE WORKUP

A full physical examination, including rigid proctoscopy, should be performed by the operating surgeon in conjunction with a digital rectal examination to determine the specific details of the lesion in question, including distance of the lesion from the anal verge in centimeters, mobility, size, percentage of circumference involvement, anterior or posterior location, and its position in relation to the sphincter complex and to the valves of Houston. As with any rectal lesion, all patients should undergo a full colonoscopy, if possible before treatment, to out rule any synchronous disease. Most lesions planned for local excision will have a preoperative histological diagnosis that is benign, but 18.8% of patients with a preoperative diagnosis of adenoma will have an invasive adenocarcinoma component on their final pathology.²⁸

The goal of the radiological preoperative evaluation is to identify if lesions are suitable for local excision by determining the radiological TNM stage, as defined by the American Joint Committee on Cancer. For rectal cancers, this is based on the depth of local tumor invasion (T stage), the extent of regional lymph node involvement (N stage), and the presence of distant metastasis (M stage). The two main local staging modalities used are magnetic resonance imaging (MRI) and endorectal ultrasound (ERUS). Concerning the assessment of the crucial circumferential resection margin, the evidence appears to favor MRI. However, when trying to distinguish between early lesions (T1 and T2 stage), the resolution of ERUS is better, with overstaging of T1 tumors observed in 11% of cases compared to 100% of those staged with MRI.²⁹ The accurate detection of involved lymph nodes

remains a diagnostic challenge for all imaging modalities, but it is likely that MRI is superior in this setting. Thus, ERUS and MRI should be considered complementary in the setting of early rectal cancer assessment. It must be noted that a biopsy or local excision of the target lesion prior to radiological assessment may lead to reactive lymphadenopathy, which may be confusing and lead to overstaging.

If a preoperative diagnosis of invasive disease is made, all patients as part of their routine workup should have preoperative systemic radiological staging to assess for metastatic disease with a computed tomography scan of the chest, abdomen, and pelvis.

OPERATIVE TECHNIQUE

Mechanical bowel preparation should be administered preoperatively and prophylactic antibiotics given. Following informed consent, patients should be administered general endotracheal anesthesia with pharmacologic paralysis. Of note, a recent series of 25 patients has reported the performance of TAMIS under spinal anesthesia, and this may be considered in high-risk patients.³⁰ The patient should be positioned for TAMIS in the high dorsal lithotomy position, which allows access to lesions in any location. Access to anterior lesions can be extremely advantageous in lithotomy, which is facilitated by gravity. This differs from TEM, where the 30° camera is situated anteriorly within the lumen of the beveled resectoscope, necessitating the patient being positioned with the target lesion placed dependently. Following antiseptic skin preparation and appropriate draping, the transanal port is inserted and sutured in place.

The pneumorectum is then established by using standard CO₂ insufflation with an initial pressure set at 15 mm Hg and flow set at 40 mm Hg/min. Recently, new insufflators have been developed (Airseal, Surgique, Connecticut), which provide improved stability of pneumorectum at lower pressures in addition to dramatically reducing intraluminal smoke.³¹ A high-definition laparoscopic camera is inserted then to visualize the target lesion through any of the working ports. A 30° or 45° camera lens is preferable for assessment of the lateral and proximal margins. Furthermore, a 5 mm camera provides more working space in the tight confines of the rectum than a 10 mm camera. Roticulating laparoscopes and even three-dimensional laparoscopes can provide further enhanced visualization with less collision. Image stabilization and sufficient visualization of the working space are dependent on an experienced assistant surgeon.

A premium should be placed on the surgical technique and quality of resection; a nonfragmented specimen with negative margins has repeatedly demonstrated the lowest risk of recurrence. The lesion margin is first scored out on the mucosa using electrocautery with a 5–10 mm margin in order to maintain orientation and proper margins of resection (**Figure 18.2a**). Excision can be performed using

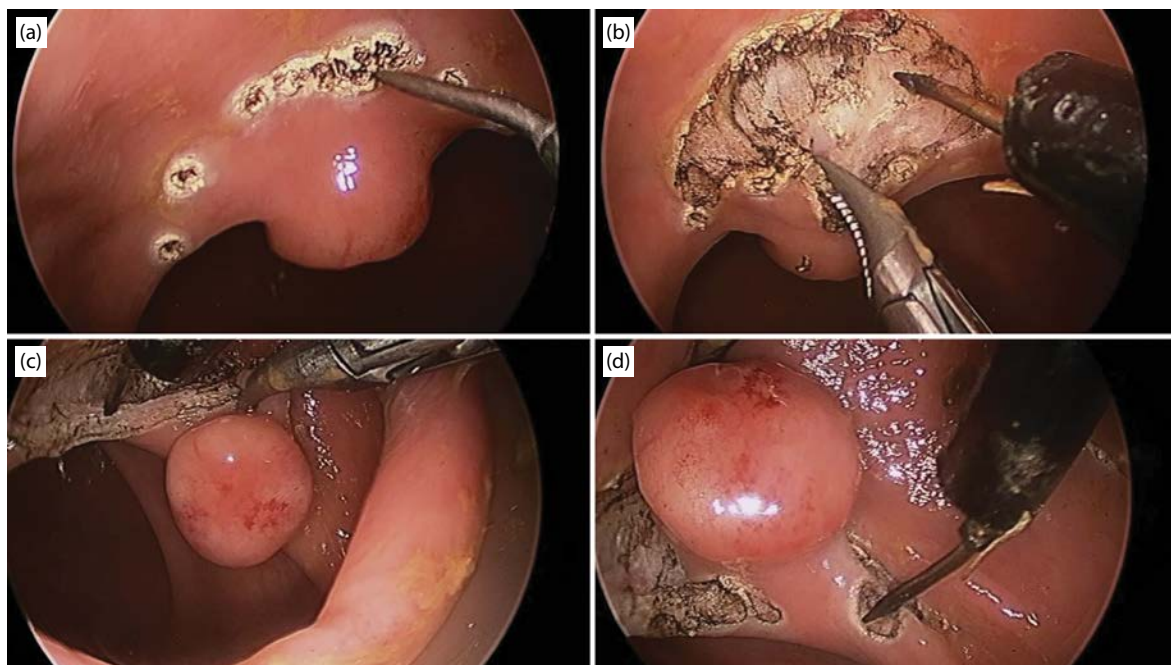


Figure 18.2 TAMIS enables positioning of the patient in the lithotomy position while operating on lesions in any quadrant of the rectum, obviating the need to place patients in the prone jackknife position for anterior lesions. (a) A 1 cm anterior, midrectal carcinoid is first marked circumferentially with a needle point monopolar cautery followed by a full-thickness proctotomy distal to the lesion. (b–d) To complete the circumferential dissection, the proximal margin of a 1 cm anterior, midrectal carcinoid is easily visualized by retracting the specimen laterally and then further anteriorly.

standard monopolar electrocautery. Use of a spatula, pin-point, or L-hook cautery allows precise dissection of the tumor and is cheap and reusable. The majority of practitioners utilize standard, straight laparoscopic instruments to perform excision, rather than roticulating instruments. Energy devices can also be used with the principal advantage being hemostasis, albeit with increased costs. Handling of the tumor or polyp with graspers should be avoided and reduced to the surrounding mucosa to limit specimen fragmentation. On all lesions known to be malignant preoperatively, a full-thickness excision must be performed with the objective of obtaining a 1 cm minimum negative margin. In contrast to the historical description of a simple full-thickness incision into perirectal fat, we support a pyramidal, volumetric excision containing an adequate specimen of perirectal fat (**Figure 18.2b–d**). This assures an adequate resection with negative margins, in addition to possibly retrieving surrounding lymph nodes for pathologic sampling. Aggressive mesorectal excision should not breach the mesorectal fascia, as it will make future total mesorectal excision challenging if it is required.

For lesions believed to be benign, a partial-thickness or submucosal excision may be performed at the discretion of the operating surgeon. Submucosal excision is often not possible in patients with multiple prior attempts at endoscopic polypectomy given the obliteration of planes from inflammation and fibrosis. Proponents of this technique cite the possibly increased risks of morbidity with deeper

defects, as well as the low risk of significant malignancy in a clinically benign lesion. In addition, submucosal excision leaves minimal inflammation and distortion should total mesorectal excision be required. However, lesions excised in a submucosal fashion are at risk of fragmentation during specimen extraction, and due to the high risk of a focus of invasion in large rectal adenomas, some authors advocate a full-thickness excision in all cases.²⁸ To facilitate dissection in the appropriate submucosal plane, the lesion can be lifted with a combination of saline and epinephrine using a laparoscopic aspiration needle.

Specimen extraction should be performed at the completion of resection and prior to defect closure to maintain specimen integrity and avoid accidental proximal migration. The majority of platforms accommodate this by allowing removal of the faceplate; however, some ports require removal of the entire device with reinsertion for closure. Irrigation of the excision bed with dilute betadine (**Figure 18.3a**), presumably for its tumoricidal and bactericidal effects, is a common practice; however, no evidence-based literature exists to support this technique.

Rectal wall or mucosal defects are then closed in a full-thickness manner completely with absorbable suture material. A running suture beginning in the lateral portion of the incision can be performed but is technically more challenging. The use of a V-Loc suture (Covidien, Mansfield, Massachusetts) can facilitate continuous closure by maintaining tension and negating the need for knot tying

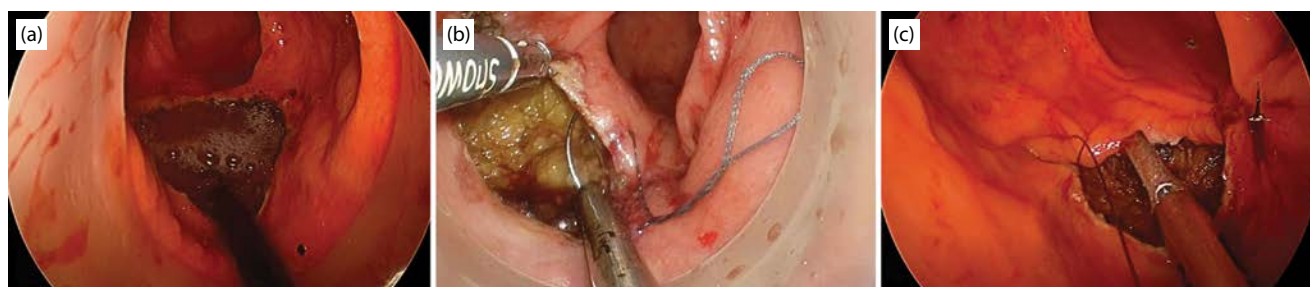


Figure 18.3 Following lesion excision and extraction, the excision bed is irrigated (a). The rectal wall is then closed in a full-thickness manner with absorbable suture material, which can be aided by the use of a barbed suture (b) to negate the need for knot tying or a knot-tying device (c).

(Figure 18.3b). Conversely, closure can be performed in an interrupted fashion with knot tying facilitated by disposable devices such as the Cor-Knot System (LSI Solutions, Victor, New York) (Figure 18.3c) or by laparoscopic knot pushers. The use of modern suturing devices can significantly shorten the learning curve at the expense of increased procedural costs. Specialized silver beads with applicators initially designed for use with the TEM system are frequently used; however, several other simpler laparoscopic knot-tying devices and methods have since become available. Whether the defect should be closed at all also remains an issue of debate. Those practitioners advocating closure state not doing so risks rectal stricture and pelvic sepsis, while those against state it increases the operating time and lesion recurrence may not be visible within the lumen. A recent series of 75 patients with 1 year of follow-up after undergoing TAMIS resection has demonstrated no difference between groups.³²

AVAILABLE PLATFORMS

Currently, transanal platforms utilized for TAMIS are determined by individual surgeon preference with five modalities in use (Table 18.1). TAMIS devices are generally easy to set up and insert—the setup time for TAMIS is typically 1–3 minutes.^{33,34} No formal, comparative data currently exist in humans. A small study in a porcine model suggested the SSL port (tm) ethicon endo-surgery may be the most suitable for transanal surgery, likely due to channel compliance in a small mammal.³⁵ However, in humans the

intrarectal retractor of the SSL port fails to expand in 13% of cases.³⁶ The GelPOINT path is the only access system to date that is custom designed for the purpose of transanal surgery, and along with the Covidien SILS port, approved by the U.S. Food and Drug Administration for transanal use.

EXPERIENCES TO DATE AND OUTCOMES

Complications

The complications attributable to TAMIS reported in the literature to date have been minor, the most common being postprocedural hemorrhage, which can occur early in the postoperative period or can be delayed in presentation.^{20,37–39} Cases of postprocedural hemorrhage that do not stop spontaneously have in all cases been managed successfully, either endoscopically or with examination under anesthesia and under sewing. Scrotal emphysema has also been reported,²⁰ which resolves spontaneously. Transient pyrexia has been reported following TAMIS, which resolved with oral antibiotic treatment,³⁸ as well as urine retention resolved with urethral catheterization.³⁷

Serious consideration must be given to the risk of inadvertent or planned intraperitoneal entry, and its recognition is imperative.²⁰ This is more likely to happen during the resection of larger lesions, with an anterior location, with an uppermost level over 10 cm from the anal verge.³⁹ The largest TAMIS series published to date has an incidence of peritoneal entry of only 2%.²⁰ In contrast, the incidence is reported as

Table 18.1 Currently available TAMIS access platforms

Device	Company
Endorec trocar	Aspide, France
GelPOINT Path Transanal Access Platform	Applied Medical, Inc., Rancho Santa Margarita, California
Gloveport	Circular anal dilator (Frankenman International, Sheung Wan, Hong Kong, China) and Alexis wound protector (Applied Medical, Rancho Santa Margarita, California)
SILS: single incision laparoscopic surgery	Covidien, Mansfield, Massachusetts
SSL: single-site laparoscopic	Ethicon Endo-Surgery, Cincinnati, Ohio
TriPort	Olympus KeyMed, Southend, United Kingdom

6%–8.6% for TEMS.^{19,39} The management of this complication must be individualized depending on the size of the defect and the patient. These defects may be repaired either transanally or with a combined laparoscopic approach. The decision to fashion a diverting ostomy must also be individualized to the patient and the patient's ability to tolerate a subsequent anastomotic leak, with reported incidence of diverting ostomy in the setting of TEM being 0%–14%.^{19,39}

Oncological

Being a relatively new and novel surgical modality, there is limited short-term oncological follow-up for TAMIS excisions. These were discussed in a recent systematic review that included 259 patients and specifically addressed the rates of recurrence of benign and malignant rectal neoplasms after TAMIS surgery.⁴⁰ Altogether, there were 2.7% incidence of recurrence reported with 7.1-month mean follow-up. A full-thickness excision was performed consistently by 60.6% of the publications reviewed, while 9.1% performed only submucosal excisions using the TAMIS platform with the remaining performing mixed full- and partial-thickness excisions.

Functional/anorectal physiology

A recent series of 25 patients undergoing TAMIS with a SILS port assessed at 3 months following surgery with a combination of endoanal ultrasonography and a fecal incontinence severity index (FISI) score did not show anal sphincter injury or fecal incontinence-related symptoms, respectively.³⁰ A further series of 37 patients undergoing TAMIS revealed an improvement in FISI score for patients with impaired preoperative continence.⁴¹ Conversely, analysis of anorectal function following TEM has shown at 3 months following excision that the mean Wexner continence score deteriorates, with associated symptoms of fecal urgency, but returns to baseline within 5 years.⁴² Postoperative manometry values at 3 months are significantly lower than at baseline but return to preoperative values at 1 year.^{42,43} Thus, there has been no demonstration to date that the performance of TAMIS adversely affects patient continence.

COMPARISON WITH EXISTING TECHNIQUES

To date, TAMIS has not been compared with TAE or colonoscopic excision. Only one pilot study in a box trainer for transanal procedures using 10 novice surgeons has directly compared TAMIS with TEM. Using an SILS Port for TAMIS, no difference was observed between the two techniques in accuracy of dissection. Dissection and suturing were quicker in the TEM group, and subjectively those assessed preferred TEM.⁴⁴ This comparison represents a limited construct and does not account for surgeon skill, training, or experience, particularly in single-site laparoscopic surgery.

Also, it does not account for the various types of TAMIS platforms available or the accessory devices commonly used by TAMIS surgeons, such as automated suturing and knot-forming devices, which aid significantly with the more technically demanding aspect of wound closure. Furthermore, the authors ignore the complexity of TEM setup and necessary patient positioning; thus, further studies in this area are required.

CONCLUSIONS

Based on currently available clinical data, TAMIS in experienced hands results in the high-quality local excision of rectal lesions with low histological margin positivity in an efficient manner with an excellent morbidity profile with no adverse effect on continence. TAMIS has enabled the performance of high-quality local excision of rectal lesions by many colorectal surgeons, integrating transanal endoscopic surgery into mainstream practice. Currently surgeon preference and device availability govern which platform is selected for use. As with all new techniques used in the management of neoplastic disease, appropriate training must be ensured, and the continued assessment and assurance of oncological outcome must be maintained.

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Diagnostic lower endoscopy

ELEANOR C. FUNG

INTRODUCTION

Examination of the lower gastrointestinal tract has evolved in the past 50 years with the advent of fiber-optic colonoscopy that allows for accurate and safe visualization of mucosal lesions to become the optimal method for both the diagnosis and treatment of the rectum, colon, and distal aspect of the terminal ileum. With guidelines endorsing colonoscopy as a screening option for colorectal cancer, the demand and need for colonoscopy will increase with the aging population. Furthermore, it highlights the importance of quality and standardization of colonoscopy as a screening procedure, which has been developed by the joint American Society of Gastrointestinal Endoscopy and American College of Gastroenterology Taskforce on Quality in Endoscopy.²²

This chapter reviews the major indications, patient preparation, technical maneuvers, complications, and alternatives when colonoscopy is not feasible.

INDICATIONS

Role for sigmoidoscopy

Sigmoidoscopy allows for the examination of the distal colon and rectum and plays a role when total colonoscopy is either not required or possible. The advantages of sigmoidoscopy include the lack of sedation or analgesia required, lower complication rate, and less intensive bowel preparation. Rigid sigmoidoscopy has been shown to be of value in the screening of asymptomatic, average-risk adults over the age of 50 or as a preliminary investigation in the workup of rectal bleeding. However, rigid sigmoidoscopy has not been as widely adopted due to the higher patient acceptance, yield, and adenoma detection rate of flexible sigmoidoscopy.²⁹ Furthermore, flexible sigmoidoscopy and

colonoscopy also allow for the treatment of polyps that cannot be afforded by a rigid sigmoidoscope.

Flexible sigmoidoscopy has been shown to be an effective screening tool for colon cancer in average-risk individuals, surveillance of anastomotic recurrence in patients with a history of rectosigmoid malignancy, and evaluation and treatment of lower gastrointestinal bleeding after an upper gastrointestinal source has been ruled out. Flexible sigmoidoscopy also can be used in conjunction with radiologic investigations, such as barium enema and computed tomography (CT) colonography, when colonoscopy is not feasible.

Role for anoscopy

Anoscopy continues to have a vital role in evaluating the anal canal, which is better visualized with a proctoscope in comparison to a flexible scope even with retroflexion. Anoscopy also allows for treatment of anal canal pathology, such as fulguration of anal warts and treatment of hemorrhoids (e.g., banding and cryotherapy).

Role for colonoscopy

The indications for colonoscopy have broadened and colonoscopy has now become the primary method for the diagnosis and treatment of lower gastrointestinal pathology. The current established indications for colonoscopy are summarized in [Table 19.1](#).

CONTRAINDICATIONS

There are few absolute contraindications to colonoscopy, which include patients with peritonitis, fulminant colitis,

Table 19.1 Indications for colonoscopy**Diagnostic**

- Colorectal Cancer Screening and Surveillance
 - Average-risk individuals for patients older than 50 years
 - Personal history of colonic polyps or colon cancer for surveillance
 - Family history of colonic polyps or colon cancer
 - Hereditary nonpolyposis colorectal cancer syndrome, familial adenomatous polyposis syndrome
 - Personal history of endometrial or ovarian cancer
- Abnormal radiologic study (e.g., CT, barium enema)
- Unexplained GI bleeding—melena, hematochezia, positive fecal occult blood test
- Unexplained iron deficiency anemia
- Assessment of severity and extent of inflammatory bowel disease or colitis
- New onset change in bowel habits (e.g., diarrhea or constipation)
- Diagnosis of colon ischemia
- Investigation of abdominal mass
- Marking a neoplasm for localization
- Intraoperative identification of a lesion not apparent during surgery (e.g., polyp, bleeding site, nonpalpable lesion, stricture)
- **Therapeutic**
 - Polypectomy
 - Treatment of bleeding lesions (e.g., electrocoagulation, heater probe, injection, laser, argon plasma coagulation)
 - Foreign body removal
 - Colonic decompression (e.g., pseudo-obstruction, volvulus)
 - Dilatation of stenosis
 - Placement of stent in partially obstructing colon cancer

toxic megacolon, or suspected bowel perforation in which air insufflation has the potential to blowout a contained perforation to freely communicate with the peritoneal cavity. Furthermore, other patient factors can preclude colonoscopy, such as inadequate bowel preparation and patients who are uncooperative or refuse to consent to the procedure.

There are also relative contraindications to colonoscopy, and it is important to carefully weigh the expected benefits with the risks and potential complications of colonoscopy. This includes patients with recent myocardial infarction, pulmonary embolus, acute active colitis or diverticulitis, ischemia, neutropenia, and suspected large bowel obstruction. In these patients, greater care to progress through the procedure should be taken due to the increased risk of perforation and complications. Special care should also be taken in patients with coagulation disorders or on anticoagulation or in patients with implanted cardiac devices that may require special management with the use of electrocautery.

PATIENT PREPARATION

Preparation is vital in order to achieve adequate visualization during colonoscopy. Patients should consume either a low-residue diet or clear liquids for at least 1–2 days prior to the procedure. Furthermore, foods or liquids that are red should be avoided in this time period as they can be mistaken for blood in the colon and can obscure mucosal details. Patients are also required to fast for a minimum of

6 hours after a light meal and/or 2 hours after clear fluid ingestion according to the guidelines of the American Society of Anesthesiologists in order to decrease the risk of complications with the administration of procedural sedation and analgesia.³

Most medications can be continued and taken with a sip of water on the day of the colonoscopy; however, there are notable exceptions. Oral iron should be stopped at least 5 days prior to the procedure as iron supplementation makes residual feces black, viscous, and more difficult to purge. Furthermore, medications for diabetes may need to be adjusted due to the decreased oral intake prior to the procedure. Decisions regarding anticoagulation must also be made, weighing the risks of bleeding and urgency of the procedure versus the risk of thromboembolic events with interruption of anticoagulation. Biopsies can be safely performed in anticoagulated patients with international normalized ratios ranging between 1.5 and 2.5.¹ Aspirin and nonsteroidal inflammatory agents can be continued safely in the peri-procedural period; however, oral anticoagulants such as warfarin, clopidogrel, and factor Xa inhibitors such as rivaroxaban would ideally be held prior to colonoscopy, particularly in high-risk procedures such as polypectomy, laser ablation, coagulation and dilatation, to decrease the risk of bleeding. Antibiotic prophylaxis is also not recommended for colonoscopy, even in high-risk patients, as the risk of infection related to both routine diagnostic and therapeutic colonoscopy is low.⁶

Good mechanical bowel preparation is also critical to allow adequate visualization of the entire colonic mucosa

for quality, speed, and completeness of lower endoscopy and are generally started 1 day prior to the procedure. Increased adenoma detection rates have also been shown to increase with improved quality of bowel preparation.²⁸ Sigmoidoscopy and anoscopy typically only require phosphate enemas to thoroughly examine the rectum and anal canal. However, for colonoscopy, a more intensive mechanical oral bowel preparation is required, and patient comorbidities must be factored in the choice of bowel preparation. Furthermore, patients with chronic constipation or a recent barium enema may require a prolonged preparation due to decreased transit. Both sodium phosphate and polyethylene glycol solutions have been found to be equally effective.¹⁵ Sodium phosphate preparations (i.e., 45 mL) are generally lower in volume; however, they should be used with caution in elderly patients and those with cardiac and renal disease due to the increased risk of dehydration as well as faster fluid and electrolyte shifts. Phosphate preparations have also been associated with endoscopic and histologic findings of colitis, which can confound pathology.²⁵ Polyethylene glycol electrolyte solutions are generally less tolerated by patients due to the higher volume (i.e., 4 L), but they have been shown not to alter the circulating blood volume and are safe to give in patients with systemic illnesses. The adequacy of bowel preparation is often described as unsatisfactory, poor, fair, and excellent, and systems have also been developed to standardize the quality of bowel preparation, such as the Boston Bowel Preparation Scale.¹⁸

Prior to the procedure, there should be a discussion with the patient regarding the needs and risk factors for sedation during the colonoscopy that can include chronic narcotic or benzodiazepine use and anxiety. Special attention should also be paid to risk factors for difficult airway management (e.g., decreased thyromental distance, nonvisualization of the uvula). Furthermore, endoscopists must obtain informed consent that includes the reasoning and indications for colonoscopy, nature of the procedure, discussion of reasonable alternative testing, and risks of potential complications, which are discussed later in this chapter. Written documentation of this consent discussion is also mandatory.

ROOM SETUP AND EQUIPMENT CONSIDERATIONS

Colonoscopy is routinely performed with flexible high-definition video colonoscopes, which contain a suction channel, air/water channel, accessory channel for therapeutic instrumentation, and insertion tube of varying length, which can be up to 160 cm. There are both adult and pediatric colonoscopes that are both effective for performing colonoscopy; pediatric colonoscopes are mainly used for female patients as well as patients with a history of abdominal surgeries. Colonoscopes can also have variable stiffness, which allows the endoscopist to stiffen the colonoscope to aid in turning corners, avoiding intestinal loops and increasing cecal intubation rates.⁴ In addition to the colonoscope, various

endoscopic equipment is also required to perform a colonoscopy, including an electrosurgery cart, grounding pads, suction traps, biopsy forceps, snares, baskets, nets, injection needles, hemostatic clips, and argon coagulation probes.

The typical room setup has the main screen placed on the patient's left side with the endoscopist standing to the patient's right side and the endoscopy assistant on the patient's left side. The patient is rolled to the left lateral decubitus position prior to scope insertion unless the patient has a colostomy and the patient is instead placed in the supine position. Carbon dioxide insufflation has also become more widely used compared to air insufflation to help reduce patient discomfort after the procedure, as carbon dioxide is more easily absorbed.¹⁹

INSERTION TECHNIQUE

Careful visual anorectal inspection and digital rectal examination prior to scope insertion is critical to identify pathology such as prostatic disease, anal fistulas, fissures, hemorrhoids, or tumors. This also allows for a pre-procedural assessment of the patient's level of consciousness and can aid in safe scope insertion by lubricating the anal canal and relaxing the anal sphincter.¹²

The scope handle is typically held in the endoscopist's left hand, and the scope is well-lubricated prior to gentle direct passage of the scope into the anal canal. Air is then insufflated until the rectal vault is reached to confirm insertion. If the patient experiences pain, the scope should be removed, and the digital rectal examination should be repeated to rule out pathology.

The endoscopist can use either one or two hands to control the dials of the scope; however, ideally, the left hand is utilized to manipulate the controls and dials of the colonoscope, while the right hand is used to manipulate and advance the shaft of the scope. If a two-handed approach is used on the controls of the scope, an assistant is required to hold or even advance the shaft of the scope. The endoscopy assistant can also assist with applying pressure to the abdominal wall to help traverse the colonic flexures and decrease loop formation.

The goals of scope insertion include minimal air insufflation, keeping the scope as straight as possible to allow for maximal control, and reaching the cecum in minimal time with minimal discomfort. Inspection of the mucosa and therapeutic procedures are largely kept for the withdrawal phase of the procedure.

SCOPE MANIPULATION

Once the scope is inserted into the anal canal, the colonoscope is carefully maneuvered to the cecum by a steady insertion, with the lumen always in view and without sharp tip angulation. If the scope is impacted against the mucosa, the scope should be withdrawn to find the lumen in order to safely advance the scope. Other techniques for safe advancement of the scope include applying torque to

the shaft with the right hand in either a clockwise or counterclockwise direction, deflecting the tip using the dials, administering additional sedation to relax the patient, inserting or withdrawing the scope in rapid short movements, applying pressure to the abdominal wall typically over the sigmoid or transverse colon, or changing patient positioning to reduce loops. The colon should only be insufflated when necessary to help with visualization and to navigate tortuous anatomy as the scope is advanced; overinsufflation can effectively elongate and distend the colon, making corners more acute and making it harder to advance the scope. Aspiration of air can also aid in deflating and shortening the colon, which not only reduces abdominal discomfort but brings the next fold closer to the tip of the scope allowing for scope advancement.¹⁹ Alternatively, meta-analyses have also shown that distending the lumen of the colon with water irrigation can aid in advancement of the colonoscope, identification of the colonic lumen, improved patient comfort, and higher adenoma detection rate in comparison to air insufflation.¹⁴

The rectum is identified by the circumferential muscle fibers, and the tip of the colonoscope should be flexed slightly and torqued around each of the three rectal valves of Houston. Once the rectosigmoid junction is reached, the tip of the scope should be deflected up and counterclockwise followed by a clockwise torque. The rectosigmoid colon can be particularly difficult to traverse in patients with a previous history of pelvic surgery as well as in patients with known diverticulosis. Generally, the lumen should be kept in view during scope advancement, but occasionally, the “slide-by” technique of pushing the scope forward when the scope is closely apposed to the colonic wall can be useful to maneuver sharply angulated corners; however, this can cause patient discomfort and is a risk factor for perforation. As such, this technique should be limited to short distances and tactile assessment of resistance by experienced endoscopists. If diverticula are present, determining the true lumen can be difficult; the true lumen is generally found in the presence of haustral folds.

Once the sigmoid colon is traversed, the scope should be untwisted to remove any torque or loops to allow ease of advancement in the descending colon. The descending colon is usually straight, with less musculature and distends more easily than the sigmoid colon due to less angulation. The splenic flexure is then reached as a sharp turn at the proximal descending colon, which can be recognized by the transmitted cardiac pulsation and bluish tint from the imprint of the spleen on the colon wall (**Figure 19.1**). The haustral folds can be used to find the direction of the lumen, which can be negotiated with downward and left-sided tip deflection. Torqueing of the shaft, abdominal pressure of the sigmoid colon, and patient repositioning to the supine or right lateral decubitus position can aid in opening up the flexure to allow for scope advancement. The scope is generally inserted around 50 cm at this juncture.

The transverse colon is then entered and easily recognized by its triangular shape. As the transverse colon is usually straight, the transverse colon is typically easily traversed

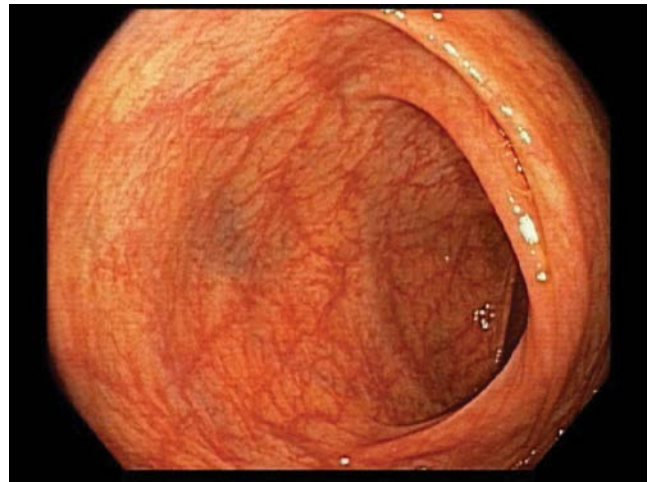


Figure 19.1 Endoscopic view of the splenic flexure.

without much tip deflection or torqueing. Withdrawal of extra air that may have built up during the procedure and reduction of loops should be performed at this juncture to allow for passage into the hepatic flexure and cecum. The hepatic flexure often appears as a classical blue shadow on the colon wall due to the liver and often is in a straight-up direction (**Figure 19.2**). The ascending colon is often coated in green mucous and has a larger diameter in comparison to the sigmoid colon. The scope can usually be advanced to the cecum by a combination of clockwise torque, suctioning of extra air, shortening the scope, and tip deflection down and to the right. Increasing the stiffness of the scope, application of abdominal pressure over the transverse colon, and repositioning the patient in the supine or right lateral decubitus position can also be useful. The scope typically shortens to between 60 and 80 cm from the anal verge. Visualizing the anatomical landmarks, such as the appendiceal orifice and ileocecal valve, clearly identifies the cecum in addition to the “crow’s foot” appearance of the



Figure 19.2 Endoscopic view of the hepatic flexure.

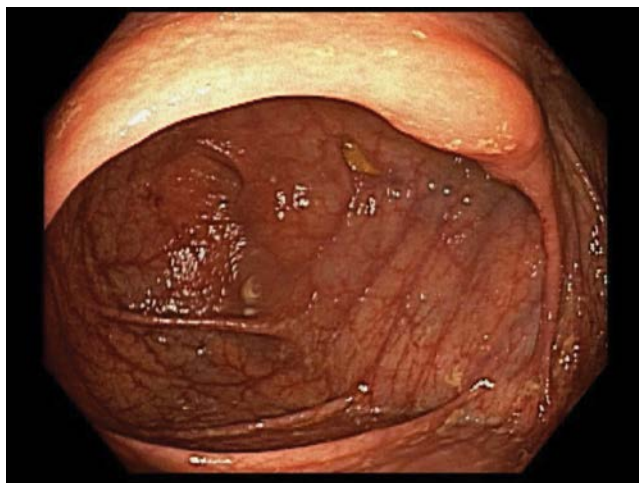


Figure 19.3 Endoscopic view of the cecum, which can be characterized by the crow's foot convergence of tenia coli in the cecum, the ileocecal valve, and appendiceal orifice.

teniae coli converging in the cecum (**Figure 19.3**). Palpation of the right lower quadrant and transillumination of the colonoscope light in the right lower quadrant can also be adjunctive signs of reaching the cecum, but this can be unreliable and sometimes not visualized. Documentation of cecal intubation by photography or videotape is important for quality assurance and medicolegal reasons. Further intubation of the ileocecal valve into the terminal ileum also confirms cecal intubation (**Figure 19.4**). Although not necessary, the terminal ileum can be intubated to 10 cm by rotating the scope until the valve is located at the bottom or top of the visual field and hooking the valve with tip deflection into the valve and gentle air insufflation to open up the valve. Failures to intubate the terminal ileum can occur due to deformity of the ileocecal valve, poor bowel preparation, or difficulty controlling the colonoscope tip due to looping.²⁷

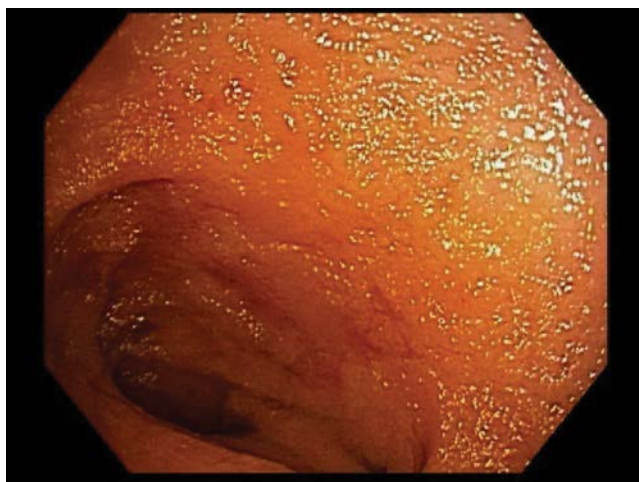


Figure 19.4 Endoscopic view of the terminal ileum.

Looping occurs due to the attachment of the sigmoid and transverse colon to a mobile mesentery and can be recognized when advancing the scope either becomes more difficult with increased resistance or there is paradoxical movement in which advancement of the scope results in reverse movement of the colonoscope tip. Reduction of loops is critical not only for successful cecal intubation, but also to reduce the risk of perforation. To reduce a sigmoid loop, the tip of the colonoscope should be hooked behind a mucosal fold and slowly withdrawn while simultaneously torqueing the shaft of the colonoscope in a clockwise manner and keeping the lumen in view. Occasionally, the scope must be advanced with the loop in place in order to successfully reduce the scope more distally, but care must be taken to ensure there is not significant resistance. The application of abdominal pressure either over the sigmoid or transverse colon and patient repositioning are also adjunctive techniques that allow for reduction of loops.²³

Unexplained pain or patient discomfort despite sedation during scope advancement should be taken seriously, and the colon should be deflated with the scope straightened out. However, if the pain continues despite desufflation and withdrawal, the scope should be removed completely, and the procedure should be abandoned.

WITHDRAWAL

Withdrawal of the colonoscope is the most critical portion of the examination, as this is when the colonic mucosa is thoroughly examined for any abnormalities. It has been suggested that the withdrawal time should be between 6 and 10 minutes to allow for adequate adenoma detection, excluding the time spent for biopsies and polypectomies. The colonoscope should be withdrawn in a slow circular motion in a coordinated manner with both torqueing of the shaft with the right hand and scope tip deflection with the left hand, allowing for careful examination of the mucosa and behind colonic folds.

Pools of liquid stool should be aspirated to allow for adequate visualization. The scope should be positioned such that the liquid is located at the bottom of the screen at 6 o'clock where the suction channel is located. If the lumen is blocked with solid material, the scope can be flushed with saline through the instrument channel, or the suction cap can be briefly removed to increase the suction strength. If the colonic mucosa becomes stuck on the scope from overzealous suctioning, the cap on the instrument port can be briefly removed to stop suctioning, which allows for the mucosa to detach from the scope.

Adequate insufflation for colonic distention should also be performed to allow for adequate visualization. Irrigation with saline or silicone particle-based antifoam solution can also help in cleaning the surface of the colon to allow for a quality examination and adenoma detection. Reinsertion of the scope and repeat withdrawal may also

be necessary to see the opposite side of the lumen. Other maneuvers to improve adenoma detection rates include patient repositioning and having experienced endoscopy assistants simultaneously examine the colonic mucosa on withdrawal.⁷ Chromoscopic, spectroscopic, and magnification techniques can also be used to enhance visualization and characterization of mucosal pathology to guide tissue sampling techniques. Lugol solution (1%–2%) and methylene blue (0.5%–1%) have been used to identify areas of intestinal metaplasia and focal carcinoma. Alternatively, spectroscopy with narrow bandwidth imaging can help define differences in tissue vascularity and may provide improved diagnosis of intestinal metaplasia and neoplasia. High-magnification endoscopes, which can magnify up to 100 times, have also been used to discriminate *in vivo* histology as well as pit patterns of non-neoplastic and neoplastic lesions.²⁴

If lesions are visualized on withdrawal, it can be difficult to correlate the exact location within the colon despite measurements made from the anal verge using the flexible scope. Right-sided and transverse lesions may be localized by the distinct colonic anatomy visualized. However, this can prove to be incorrect unless the appendiceal orifice or ileocecal valve is definitively identified in proximity of the lesion.

Prior to colonoscope removal, the scope tip should be retroflexed in the distal rectum to inspect the distal rectum and anus. In order to do so, the scope should be withdrawn to approximately 10 cm from the anal verge with the tip maximally deflected upward and advancing the scope into the rectum with simultaneous rotary torque and air insufflation (Figure 19.5). This maneuver can cause patient discomfort and may not be possible in patients with a narrow or inflamed rectum. If rectal pathology is found, rectal lesions are most accurately localized by rigid endoscopy at the completion of colonoscopy.



Figure 19.5 Endoscopic retroflexion view of the distal rectum and anus.

TISSUE SAMPLING TECHNIQUES

Pathology visualized on colonoscopy should be either sampled or removed to document and/or remove neoplasia or other gastrointestinal pathology to guide medical or surgical treatment. Tissue sampling includes biopsies, brushings, or polypectomies, and the specimens can be sent to histology, cytology, or microbiology.⁸ Critical to tissue sampling is adequate visualization of the lesion. If electrosurgery is being used, colonic gas should be evacuated and replaced with insufflated air or carbon dioxide to reduce flammable gases within the colonic lumen to prevent the extremely rare complication of gas explosion.

Cold biopsy using biopsy forceps is commonly used to sample abnormal colonic mucosa for the diagnosis and documentation of inflammatory bowel disease, ischemia, colitis, or cancerous lesions. Polypectomies of polyps that are less than 5 mm in size can also be performed successfully using cold biopsy forceps. Spiked biopsy forceps are typically used to facilitate multiple biopsies during a single pass of the forceps without specimen loss. Four-quadrant biopsies along the entire length of the colon should be taken in patients with ulcerative colitis to document the extent of inflammation and to rule out dysplastic lesions. Random colonic biopsies should be taken in patients with chronic diarrhea to rule out microscopic or idiopathic colitis. For suspicious polyps or cancerous lesions, which can appear as irregular fungating polyps or constricting annular or ulcerated lesions, six careful biopsy specimens should be taken to ensure a tissue diagnosis.¹³

Snare polypectomy is most commonly used for polyps greater than 5 mm in which a snare with or without cautery is used to remove pedunculated polyps at the level of noninvolved stalk tissue. The polyp should ideally be oriented at 6 o'clock in the endoscopic field to facilitate snaring of the lesion in the visual field (Figure 19.6).



Figure 19.6 Example of a pedunculated polyp amenable to snare polypectomy.

The scope should be advanced beyond the lesion prior to deployment and manipulation of the snare around the stalk of the lesion. The snare should then be maneuvered in and out to ensure that adjacent or deeper tissue is not incorporated into the snare. If electrocautery is used, monopolar coagulation current in short bursts should be applied until the tissue at the polyp base turns white and the snare is tightened to allow excision. Sessile polyps may need elevation of the lesion from the underlying intestinal wall using submucosal injection of saline, hypertonic saline, or hyaluronic acid prior to snare polypectomy. Injection should begin at the far end of the lesion and raised toward the endoscopist's field of vision to allow for adequate visualization. Piecemeal excision can be performed if the polyp is greater than 2 cm in size, is not easily constricted by the snare, or is in areas that are prone to perforation, such as the cecum. Removal of all pieces is recommended to allow for complete excision and proper histologic analysis.

Polyp retrieval is then achieved either by suction into a suction trap for small polyps or endoscopic retrieval nets for larger polyps. Alternatively, the polyp can be suctioned into the suction tip while the scope is withdrawn with the polyp in view. If the polyp is lost or unable to be retrieved endoscopically, the stool can be strained for polyp retrieval.

Polyps with submucosal involvement, greater than 2 cm in size, span more than 1 haustral fold or span greater than one-third circumference may require endoscopic submucosal resection, which is described in [Chapter 20](#), or if not, surgical resection. Consideration should also be given to tattooing the lesion with India ink with four circumferential submucosal injections of 1 mL just distal to the lesion to allow for easier identification on repeat endoscopy or surgical resection¹⁷ ([Figure 19.7](#)).

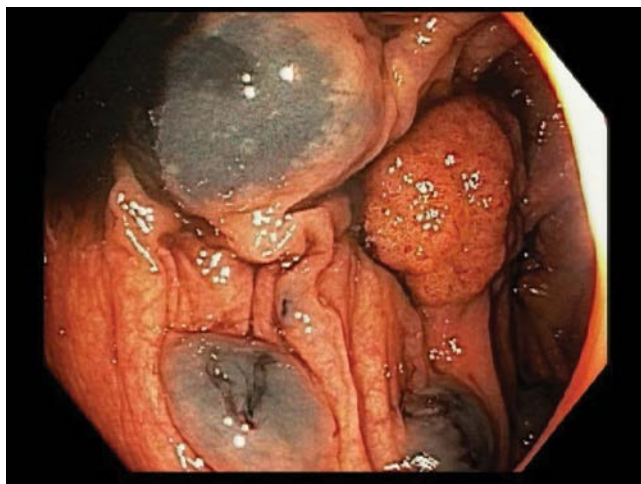


Figure 19.7 Grossly malignant lesions can be marked distally with India ink blue tattoo injections in the submucosal space for easy identification during surgical resection.

COMPLICATIONS

Colonoscopy is an invasive procedure, and as such, complications can occur. Reported complications are approximately 1:1,500 for diagnostic colonoscopy and 1:100 if a polypectomy is performed. The mortality rate related to colonoscopy is approximately 0.007%.¹⁰

The majority of complications from colonoscopy are from oversedation, which may induce cardiorespiratory abnormalities, such as respiratory depression and cardiac arrhythmias. Patients can also experience a vasovagal response with profound hypotension and bradycardia from advancement of the colonoscope. This can be treated with cessation of scope movement and intravenous fluid administration.⁹

Bleeding can either occur by scope trauma or inadequate control of a potential bleeding source, which is increased and associated with polypectomy. The risk of bleeding from colonoscopy is approximately 1%–2% and can be delayed for up to 2 weeks after therapeutic procedures, classically after a hot-biopsy or snare polypectomy.¹¹ Adjuncts to achieve hemostasis endoscopically include epinephrine injections, endoscopic clips, and coaptive techniques. Epinephrine injections are typically performed using up to 10 mL of dilute 1:10,000 epinephrine solution injected in the submucosal plane with a spreading wheal made around the area of bleeding to create a submucosal tamponade and cause vasospasm of the feeding vessels. Epinephrine injections can also be used in conjunction with thermal therapies to yield the best results in high-risk settings. Options for thermal energy include the use of probes via the biopsy channel, which create both pressure and tamponade of the bleeding point with simultaneous application of thermal energy for coagulation. Endoscopic clips and loops can also be used to control visible vessels and other focal bleeding points, which can be particularly useful when thermal energy may be too dangerous or has already been attempted without success. However, despite these best efforts, bleeding may still occur in the postprocedure period. In most cases, bleeding is self-limited, but repeated endoscopy may be necessary if bleeding persists or is causing hypotension. In circumstances in patients with extreme hemodynamic instability or failure to achieve hemostasis endoscopically, they may require radiologic intervention such as angiographic embolization or surgery.²⁷

The major complication from colonoscopy is bowel perforation, which occurs in 0.17% of procedures.²¹ Perforations can occur by the insertion trauma from the instrument tip or shaft, inappropriate air pressure, or blowout of a diverticulum or diseased colon or thermal injury during polypectomy. Risk factors for perforation include advanced age, multiple comorbidities, diverticulosis, colonic obstruction, resection of polyps greater than 1 cm in size, right-sided polypectomies, and endoscopist inexperience.⁵ The risk of perforation increases with the increased difficulty of the examination and reduced mobility of the colon, such as in patients with adhesions and fixed loops, previous radiation therapy,

malignancy, or severe diverticular or inflammatory diseases. Perforations recognized during colonoscopy may be amenable to endoscopic clip closure and if the perforation is accessible.¹⁶ Patients who experience unusual pain and tenderness following colonoscopy should prompt close and radiologic investigation. The suspected diagnosis can be confirmed with upright chest and abdominal x-rays demonstrating the presence of pneumoperitoneum or retroperitoneal air. A CT abdomen/pelvis with water-soluble contrast can also be obtained, which has a higher sensitivity for detecting extraluminal air. However, free air may be absent, such as in postpolypectomy syndrome that has been found to likely represent a microperforation or full-thickness bowel injury without frank perforation. Immediate management includes keeping the patient on bowel rest in addition to intravenous fluid and broad-spectrum antibiotic administration. The management of postpolypectomy syndrome differs from frank perforation in that it may respond with conservative management. Immediate surgical intervention is the treatment of choice for frank perforation in patients with diffuse peritonitis, hemodynamic instability, or concomitant colonic lesions requiring surgery.²⁰

Despite colonoscopy being considered the gold-standard investigation to image the colon, colonoscopy is not 100% accurate, and there is an inherent miss rate for the detection of adenomas and, rarely, cancerous lesions, that is approximately 5%. Inadequate bowel preparation, difficulty during the procedure, short examination time, and small, flat or depressed lesions are risk factors for missing pathological lesions. If solid stool is found or copious liquid stool cannot be irrigated off the colonic wall, the procedure should generally be abandoned as the quality of the examination is inadequate and a repeat examination with a prolonged bowel preparation should be performed.²⁷

ALTERNATIVES TO LOWER ENDOSCOPY

There are instances in which colonoscopy is not feasible, either due to patient intolerance, inability to reach the cecum, inadequate bowel preparation, or patient refusal. Colonoscopy can be reattempted either with improved preparation or alternative sedation strategies. However, even in the most experienced hands, there is a 3%–5% chance of an incomplete colonoscopy.²⁶

As such, radiographic imaging can be used to assess the colon, such as barium enema and CT colonography. Barium enemas or modified enema studies with water-soluble contrast agents are limited in utility due to the inability to assess fine mucosal details such as small polyps or early cancers.³⁰ As such, CT colonography is often the chosen alternative to colonoscopy, as it has been viewed as a safe and noninvasive test. Mechanical bowel preparation and insufflation of the colon via a rectal tube are still required for CT colonography for adequate assessment of the colonic mucosa. It has been found to have relatively comparable rates of polyp

detection for lesions at least 8 mm in diameter. However, when abnormalities are detected or findings are indeterminate, colonoscopy is still required for visualization and possible therapeutic intervention.²

CONCLUSION

Colonoscopy has become the primary method of imaging the colon for diagnosis, treatment, and prevention of colorectal disease. Technological advancements in instrumentation and visualization have allowed for expansion in the indications and utilization of colonoscopy as a diagnostic and therapeutic tool. As a result, quality assurance measures and adequate training in endoscopy have and will become increasingly important to improve colonoscopy performance.

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Endoscopic procedures of the pancreas for complications of pancreatitis

AJAYPAL SINGH AND ANDRES GELRUD

INTRODUCTION

Acute pancreatitis is a leading cause of hospitalization for gastrointestinal disorders with approximately 275,000 admissions in 2009 and more than 2 billion U.S. dollars in annual health-care costs.^{1,2} The overall mortality among patients with acute pancreatitis is around 5%, but patients who develop severe acute pancreatitis have mortality rates as high as 15%³ and even higher when multiorgan failure is present. While the majority of patients with acute pancreatitis have interstitial edematous pancreatitis, less than 10% of patients develop necrotizing pancreatitis characterized by necrosis of either pancreatic or peripancreatic tissue or both. This necrosis can develop over days after the onset of pain and hence can be missed on imaging done very early in the disease course or during initial presentation.^{4,5} The revised Atlanta classification of pancreatic and peripancreatic fluid collections was published in 2012 and categorizes these collections based on the presence or absence of solid material within and well-defined capsule surrounding these collections.⁶ The four types of fluid collections associated with acute pancreatitis are acute fluid collection (AFC), pancreatic pseudocyst (PP), acute necrotic collection (ANC), and walled-off necrosis (WON). AFCs develop early in acute interstitial edematous pancreatitis, do not contain any solid debris, are homogenous on contrast-enhanced imaging, do not have well-developed capsule, and usually resolve without any intervention. If these persist beyond 4 weeks, they develop a well-demarcated capsule and are known as pseudocysts that also do not contain any solid material. ANC, usually seen during the first 4 weeks in necrotizing pancreatitis, contains both fluid and necrotic components and

is without a well-demarcated wall. These can develop a well-defined encapsulation after 4 weeks and are known as WON. Infection can occur in approximately 40%–70% of necrotizing pancreatitis patients and dramatically increases the mortality from 15% for sterile necrosis to 40% in infected necrosis.⁷ It is usually difficult to differentiate between AFC and ANC during the first week or two of acute pancreatitis, since both can appear homogenous with fluid consistency on contrast imaging; hence, imaging should be delayed for the first 2 weeks after admission if clinically feasible.

The majority of acute collections resolve within a few weeks, while less than 10% of these persist beyond 4 weeks, develop a well-demarcated capsule, and evolve into either pseudocysts or WON. In a recent study, it was shown that 41% of patients with ANCs had spontaneous resolution, while 49% evolved into WON.⁸ It is of utmost importance to carefully select patients who require intervention for pancreatic fluid collections. Only symptomatic collections require intervention, while asymptomatic collections should be conservatively managed irrespective of the size. The approaches to drainage or debridement can be endoscopic, surgical, percutaneous, or a combination therapy. Common indications that require intervention include obstruction of adjacent viscera (gastric outlet obstruction, pancreatobiliary obstruction) ([Figure 20.1](#)), abdominal pain, infection ([Figure 20.2](#)), and less frequently, rupture or bleeding. There is no role for endoscopic drainage of acute collections, and if possible, surgical intervention should be avoided in the first 4 weeks since a direct correlation exists between success of endoscopic intervention and degree of encapsulation,⁹ and early intervention is associated with poor outcomes.¹⁰

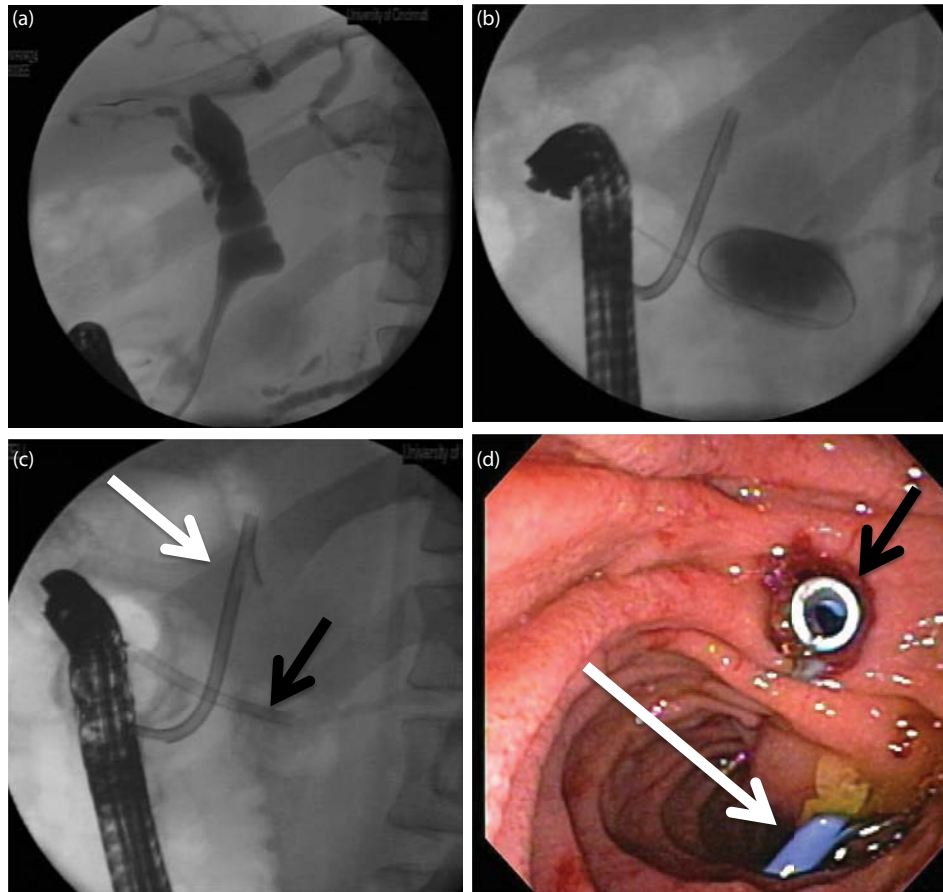


Figure 20.1 A 32-year-old female presents 5 weeks after an episode of biliary pancreatitis with painless jaundice. She was found to have a small pancreatic pseudocyst compressing the distal common bile duct. (a) Endoscopic retrograde cholangiopancreatography (ERCP) with distal common bile duct obstruction and proximal dilation. (b) ERCP image of pancreatic pseudocyst compressing the bile duct (with stent in place). (c) Biliary stent and transduodenal short stent (black arrow) and biliary stent (white arrow). (d) Endoscopic image of biliary stent (white arrow) and transduodenal stent (black arrow).

MANAGEMENT OF SYMPTOMATIC PSEUDOCYST

The incidence of AFCs in patients with acute edematous pancreatitis is approximately 40% with pseudocysts developing in only 10% of these patients. Endoscopic transmural drainage of pseudocysts was initially described in 1985 and should be the initial intervention of choice in patients with symptomatic pseudocysts.¹¹ A randomized prospective trial comparing endoscopic drainage with surgery for symptomatic pseudocysts showed that while both modalities were equally efficacious, endoscopic drainage was associated with significantly shorter length of stay and lower hospital costs.¹² It is very important to differentiate between pseudocysts and WON, since the endoscopic management is completely different. Sometimes computed tomography (CT) imaging is unable to identify the presence of solid components in a walled-off collection; hence, endoscopic ultrasound or magnetic resonance imaging may be needed to rule out the presence of solid debris. It is also important to differentiate pancreatic pseudocysts

from cystic neoplasms—a previous history of pancreatitis is key in making the distinction. The usual approach to drain these PPs depends on the location, size, anatomy, and also presence or absence of pancreatic duct disruption. Many endoscopists will attempt endoscopic retrograde cholangiopancreatography (ERCP) to evaluate the main pancreatic duct and determine the presence of a ductal disruption or a communication with the fluid collection to attempt transpapillary drainage, and others will proceed directly with transmural drainage and placement of one or more stents.

MANAGEMENT OF SYMPTOMATIC WALLED-OFF NECROSIS

Indications and timing for intervention

Successful management of WON requires a multidisciplinary approach with involvement of gastroenterologists, radiologists, pancreatobiliary surgeons, nutritionists, and critical

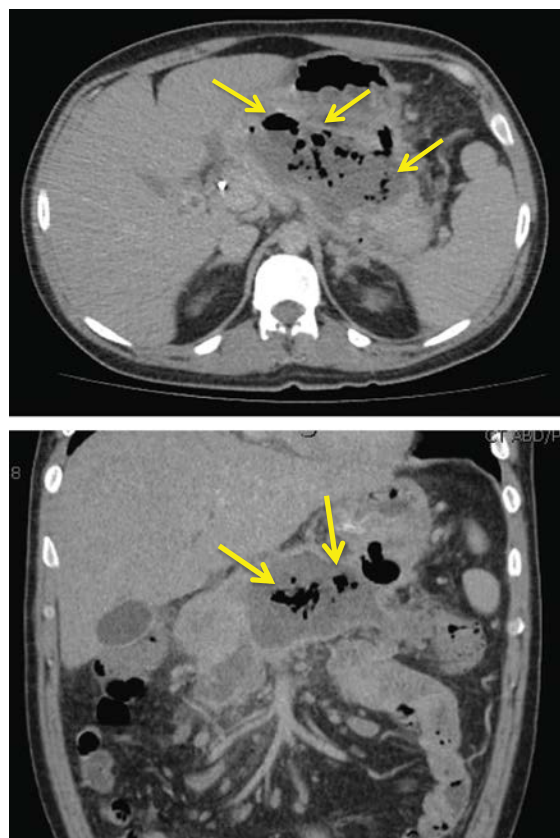


Figure 20.2 CT scan image (axial and coronal views) of infected WON with the presence of gas within the collection (yellow arrows).

care specialists. Optimal nutrition and, if present, management of sepsis and organ failure are of paramount significance. It is important to understand that asymptomatic collections do not need to be drained irrespective of the size and location. Intervention is usually needed in patients with high suspicion or documented infection in the collection (**Figure 20.2**), obstruction of viscera, persistent symptoms (pain, decreased oral intake, nausea/vomiting, and early satiety) and disconnected duct syndrome (since these are less likely to resolve without intervention, particularly if pancreatic ascites is present). Over the last few years, few studies have reported that even selected patients with infected WON who are clinically stable can be managed without debridement with supportive care, antibiotics, and percutaneous drainage.^{15,16} Prior to the advent of endoscopic drainage, symptomatic WONs were traditionally managed by surgical debridement, which usually required multiple sessions and had significant morbidity, including organ failure, external fistulas, and incisional hernias. Even though endoscopic drainage of PP was reported in 1985, endoscopic drainage and lavage of organized necrosis was described in 1996,¹³ and endoscopic transmural retroperitoneal necrosectomy was initially described in 2000 by Siefert et al. from Germany.¹⁴

Endoscopic intervention/necrosectomy must be avoided until a well-defined capsule has developed and success

of drainage/debridement has been shown to be directly associated with the degree of encapsulation.^{17,18} Besselink et al.¹⁹ showed that mortality after surgical necrosectomy in patients with necrotizing pancreatitis (more than 80% with infected necrosis) decreased significantly with increasing the time interval from initial admission (8% versus 45% versus 75% for more than 30 days, 15–29 days, and 1–14 days, respectively; $p < 0.001$).

Which modality to choose: The step-up approach

Prior to the development of endoscopic necrosectomy, early surgical debridement was used very frequently in patients with suspected infection of pancreatic necrosis. Open necrosectomy with wide drainage with placement of abdominal drains for lavage was the most common approach. This usually required repeat laparotomies and was associated with significant morbidity and mortality ranging from 11% to 50%.^{20–22} The reintervention rates in high volume series from Europe and the United States have been high (30%–70%). A large volume study from Boston in which patients with suspected pancreatic necrosis underwent single-step debridement and abdominal closure were noted to develop postoperative pancreatic fistulas in 41%, enteric fistulas in 15%, endocrine pancreatic insufficiency in 16%, and exocrine insufficiency in 20% of patients; 57% of patients also required prolonged postoperative intensive care stay.²¹

Over the last couple of decades, along with development of endoscopic necrosectomy, other methods of pancreatic necrosis debridement have been developed and include percutaneous, retroperitoneal, and minimally invasive approaches. The percutaneous approach involves placement of percutaneous drains into the collections under ultrasound or CT guidance followed by frequent flushing of the cavity (**Figure 20.3**). The three main advantages of percutaneous drainage are that the drain tract can be used in the future

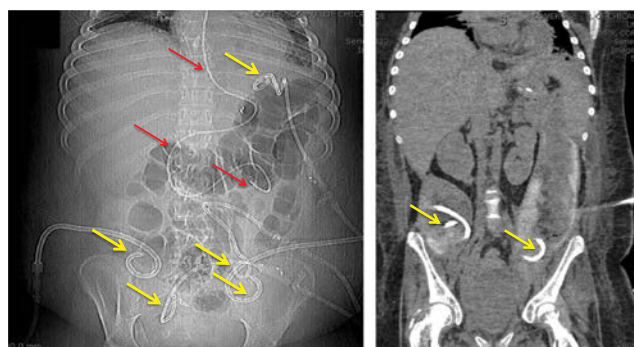


Figure 20.3 Abdominal x-ray and CT scan image of extensive pancreatic and peripancreatic necrosis (not encapsulated) extending toward the pelvis with five percutaneous drains (yellow arrows) and a naso-jejunal feeding tube (red arrow).

for further necrosectomy (either video assisted or endoscopic), the complications and mortality associated with percutaneous drainage are low, and percutaneous drainage can be performed in critically ill patients early in the course of disease when a well-defined capsule is not present. But since no debridement is done initially, the success rate is not very high, and more invasive interventions are usually needed, particularly in large cavities or if infection is present. Even though the data are mainly retrospective and from small-sized studies, approximately 44% patients can avoid further invasive interventions after percutaneous drainage of pancreatic necrosis.²³ In a systematic review, Baal et al. evaluated percutaneous catheter drainage as the primary intervention for management of pancreatic necrosis.²⁴ They found that no additional surgical intervention was needed in 55.7% of the patients, and mortality in the percutaneous catheter drainage group was 15.4%.

Even though the treatment approach for WON has shifted from surgical debridement to endoscopic necrosectomy, randomized data to support the management were

lacking until recently. In the last decade, multiple nonrandomized studies showed efficacy of endoscopic transmural necrosectomy in managing pancreatic and peripancreatic necrosis. Initially managed primarily with surgical debridement, it was associated with high morbidity (34%–95%) and mortality (6%–25%).^{21,25–27} Subsequently, other minimally invasive techniques were developed, including percutaneous catheter placement, laparoscopic transperitoneal, and video-assisted retroperitoneal debridement (VARD), that have been shown to be associated with lower rates of complications and multiorgan involvement. Baron et al., for the first time in 1996, published a case series of 11 patients who had cystgastrostomy and nasocystic irrigation for WON, and transluminal direct endoscopic necrosectomy was first reported in 2000.¹⁴ Since then multiple studies have shown the efficacy of transgastric access into the retroperitoneum and debridement of necrotic tissue followed by placement of stents to allow for subsequent drainage^{28–30} (Figures 20.4 through 20.7). Endoscopic ultrasound (EUS) guidance should be used when puncturing the gastric wall

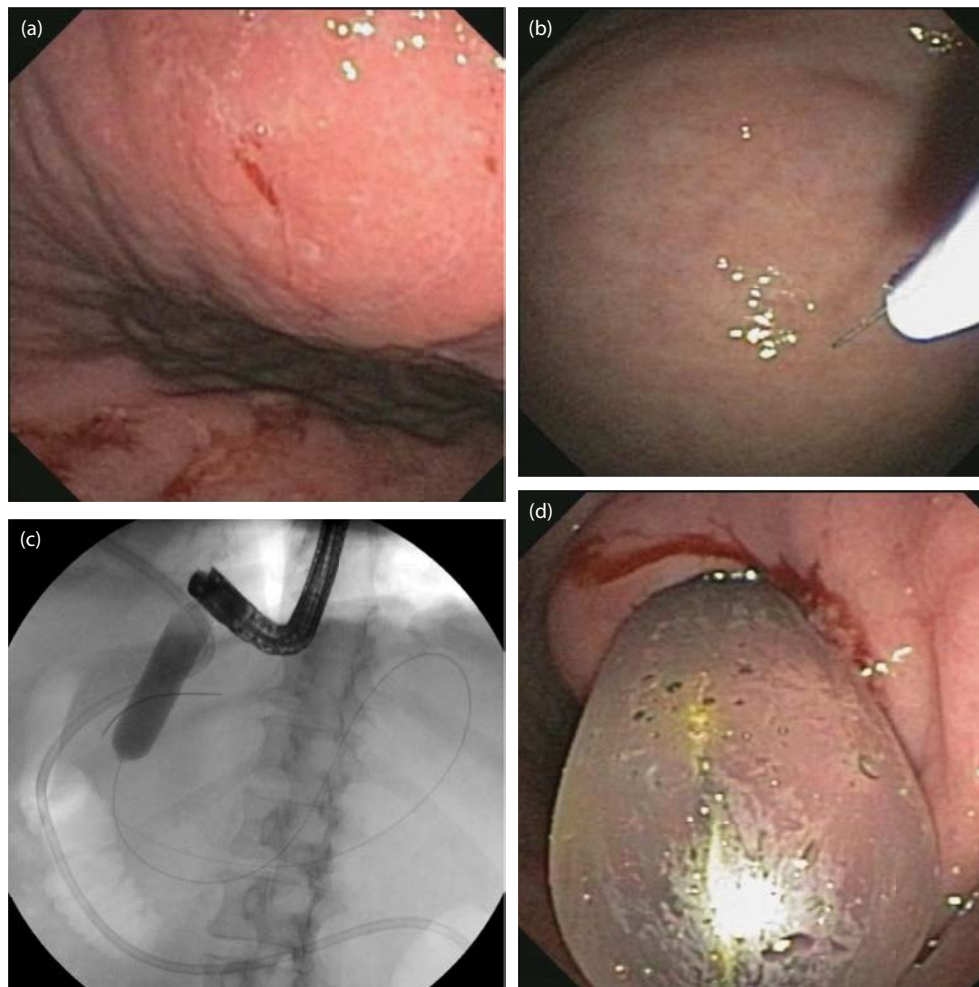


Figure 20.4 Direct endoscopic guided access of pseudocysts and necrosis. (a) Bulge present in the posterior wall of the gastric body and (b) needle knife in place. (c) Fluoroscopic view of guidewire inside the cavity with inflated balloon. (d) Endoscopic view of the through-the-scope balloon (18 mm) for fistula tract dilation.

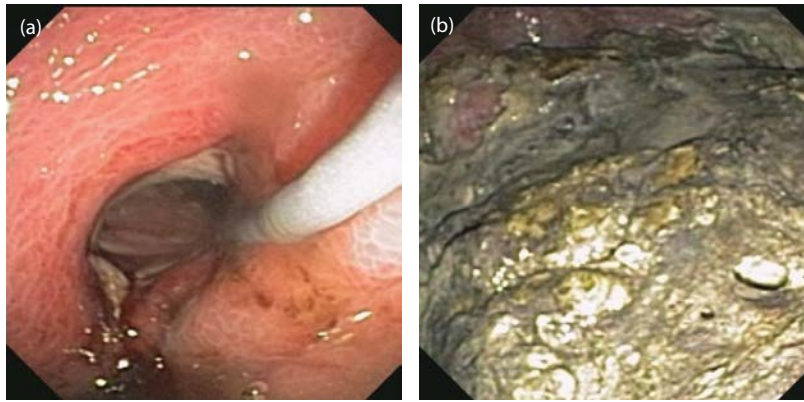


Figure 20.5 (a) The cystgastrostomy tract after balloon deflation. (b) Appearance of the cavity upon entry. Large amount of necrotic debris.

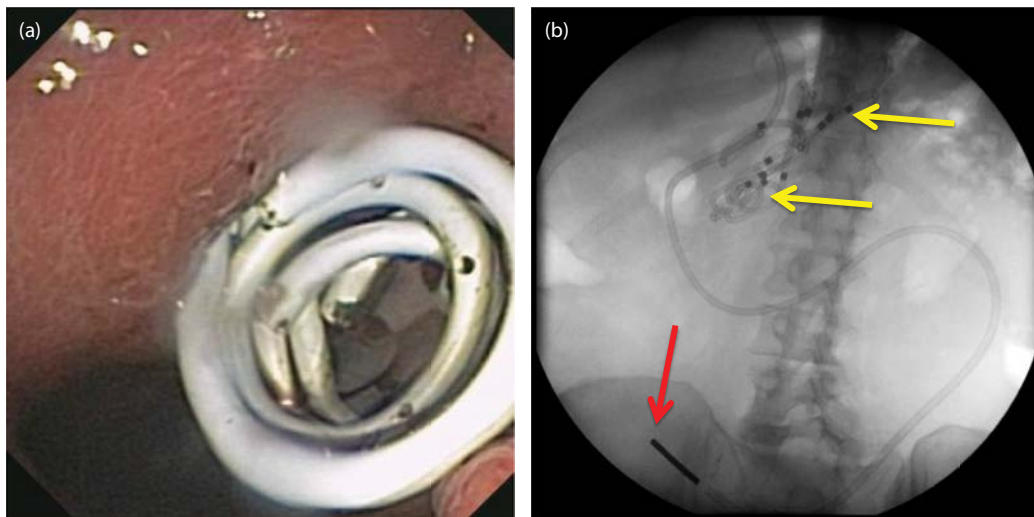


Figure 20.6 (a) Multiple soft double pig tail stents are placed to keep the patency of the cystgastrostomy site and facilitate further drainage. (b) Abdominal x-ray with multiple double pig tail stents at cyst gastrostomy site (yellow arrows) and tip of nasojejunal feeding tube to assure adequate nutrition (red arrow).

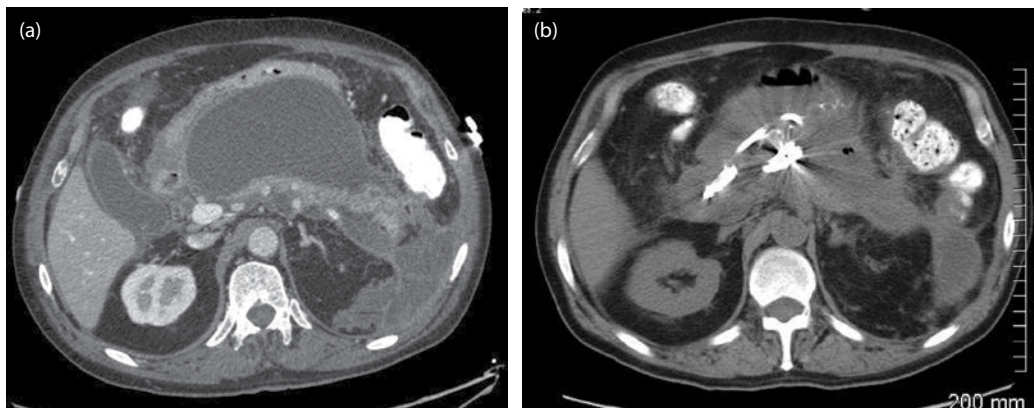


Figure 20.7 The previous patient CT images before and after endoscopic necrosectomy. (a) CT scan with well-demarcated WON compressing the gastric lumen. (b) Four weeks after successful transgastric endoscopic necrosectomy.

if a definite bulge is not seen endoscopically or if gastric varices are present.³¹ EUS also helps assess the degree of necrotic debris inside the cavity. With most training programs offering EUS and ERCP training and new fully covered lumen-apposing stents that can be deployed using the EUS scope (Figure 20.8), many new therapeutic endoscopists are doing exclusively EUS-guided drainages. A multicenter study from the United States involved 104 patients with symptomatic WON who underwent direct endoscopic necrosectomy with successful resolution in 91% patients after a mean period of 4.1 months and a median of three procedures.⁹ Periprocedural complications occurred in 14/103 patients and included significant bleeding requiring blood transfusion and two deaths. Even though data comparing endoscopic versus surgical necrosectomy are limited, in a randomized controlled trial involving 20 patients with infected necrotizing pancreatitis, endoscopic transgastric necrosectomy was compared with surgical necrosectomy, (VARD, and open necrosectomy if VARD not feasible).²⁸ Patients who underwent endoscopic transgastric necrosectomy had lower postprocedure IL-6 levels ($p = 0.004$), lower incidence of new-onset multiple organ failure (0% versus 50%; $p = 0.03$), lesser pancreatic fistulas (10% versus 70%, $p = 0.02$) and a nonsignificant trend toward lower mortality (10% versus 40%; $p = 0.3$).

In the first randomized trial comparing endoscopic transgastric with surgical necrosectomy (PENGUIN trial: the Pancreatitis Endoscopic Transgastric versus Primary Necrosectomy in Patients with Infected Necrosis), Bakker et al. showed that endoscopic necrosectomy reduced pro-inflammatory response and was associated with markedly decreased incidence of major complications or death (20% versus 80%).²⁸ The endoscopic approach involved transgastric puncture, balloon dilation, followed by retroperitoneal drainage and necrosectomy, while the surgical approach consisted of VARD or was laparoscopic if VARD was not feasible.

A step-up approach, which aims at control of the infection source rather than complete removal of infected necrosis, has been recently proposed. In the PANTER trial (minimally invasive step-up approach versus open necrosectomy in patients with acute necrotizing pancreatitis), Van Sanvoort et al. showed that the primary endpoint of death or major complications was seen in 40% patients with minimally invasive step-up compared to 69% of patients who underwent primary open necrosectomy (relative risk = 0.57, 95% confidence interval 0.38–0.87, $p = 0.006$). The limitations of this study included not using laparoscopic necrosectomy in patients undergoing surgery. Also only 5% of the patients in the step-up group underwent endoscopic necrosectomy, while others received percutaneous drainage followed by VARD as needed. More trials comparing percutaneous drainage, VARD, endoscopic necrosectomy, and hybrid (combination of drainage) techniques are needed. Most importantly, a multidisciplinary approach involving intensive

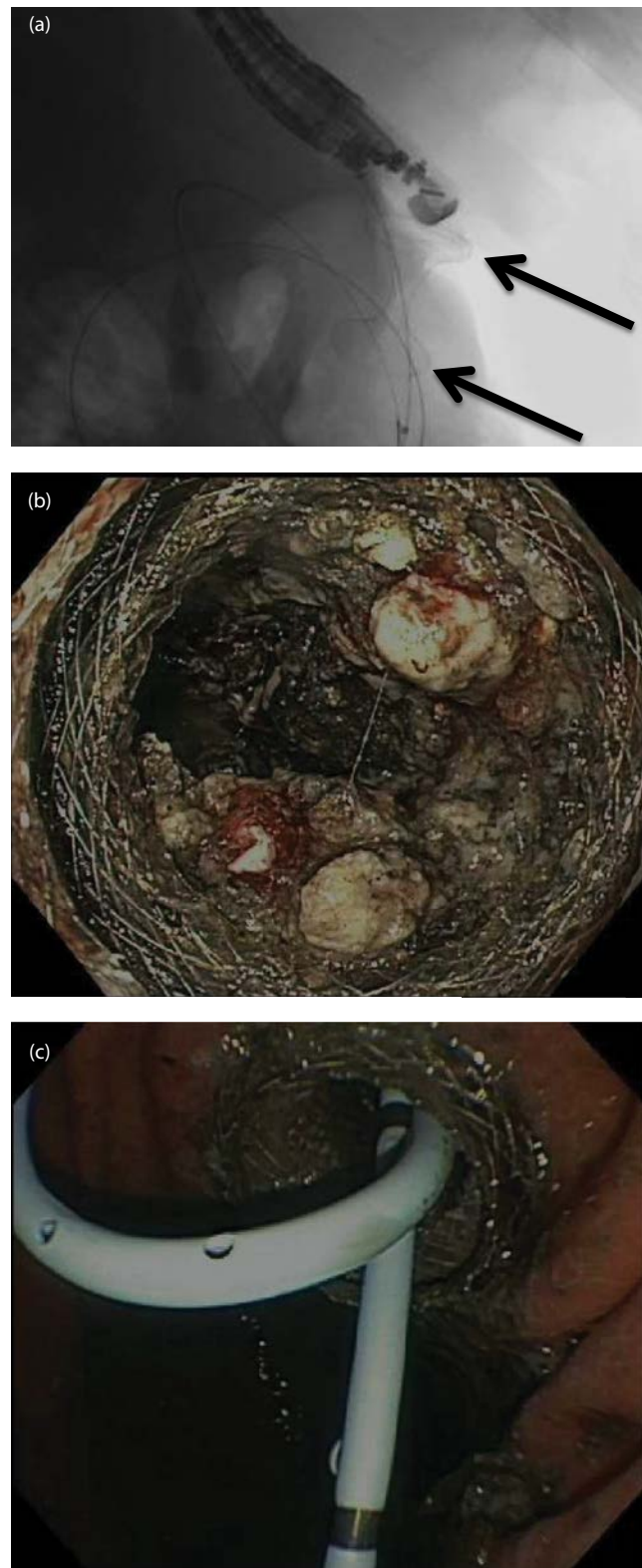


Figure 20.8 WON treated via fully covered lumen-apposing stent. (a) EUS-guided placement of transgastric metal stent (arrows). (b) Access to the WON via preexisting stent with subsequent debridement. (c) Placement of two plastic stents to assure patency of metal stent.

care specialists, gastroenterologists, surgeons, and interventional radiologists should be adopted in these patients. Local expertise, resource availability, and referral options should also play an important role in guiding management until standardized guidelines are developed.

The data about long-term outcomes of endoscopic transmural necrosectomy are still limited but promising. Seifert et al. showed an 84% clinical success rate with a 26% complication rate and 7.5% mortality in 93 patients undergoing endoscopic necrosectomy after a mean follow-up interval of 43 months. The mean number of endoscopic procedures required was six, and only 4% of patients required surgical interventions, while 16% had recurrent pancreatitis episodes.²⁹ In a recently published study, Bang et al. showed that an algorithmic approach to managing WON based on the step-up approach yielded a 91% clinical success rate compared to the 60% clinical success achieved with a conventional approach.

CONCLUSION

Even though prospective, randomized data are limited, available evidence strongly points toward benefits of a minimally invasive or step-up approach for managing patients with WON. Careful selection of patients requiring intervention and local expertise is very important. Those who require intervention despite aggressive supportive treatment should receive endoscopic transmural necrosectomy or combined endoscopic and percutaneous drainage first. Endoscopic therapy can be performed using an EUS scope or a duodenoscope, and we favor doing the procedure with general anesthesia and carbon dioxide. Endoscopic treatment can be repeated in the following days, depending on the size of the collection. If the collection cannot be reached endoscopically or the collection is too large with necrotic content, combination therapy including VARD should be considered. Minimally invasive necrosectomy should be done if the above measures fail, and open necrosectomy with abdominal lavage should be reserved

only for rare patients who continue to show clinical deterioration despite step-up therapy.

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Endoscopic procedures of the biliary tree

JEFFREY M. MARKS AND PING PAN

INTRODUCTION

Despite various changes in imaging and operative techniques, endoscopic retrograde cholangiopancreatography (ERCP) continues to be both an integral part in treatment of biliary pathology and one of the more technically challenging endoscopic procedures. The ability to successfully and safely perform an ERCP requires sufficient practice and advanced endoscopic techniques beyond basic endoscopic skills normally used for more straightforward procedures.

PREPARATION

Prior to beginning the procedure, the preparation is already different compared to standard esophagogastroduodenoscopy. The patient is placed in the prone position for best success with biliary cannulation, and fairly generous moderate sedation is given. Pre-procedural and occasional 48-hour post-procedural antibiotics are given to decrease the risk of cholangitis in high-risk patients such as those with known prostheses, multilevel biliary obstructive disease, concurrent pseudocysts, and those in whom successful ERCP with relief of obstruction is expected to be difficult.^{1,2}

INDICATIONS

Past indications for the performance of ERCPs encompassed both diagnoses of biliary diseases and therapeutic interventions.³ With the advent of magnetic resonance cholangiopancreatography (MRCP), indications for ERCP have shifted as MRCP has assumed the role for the diagnosis of more complicated biliary pathologies such as strictures, masses, and anatomic abnormalities without the complications associated with the more invasive procedure.⁴ MRCP is, however, limited in that it does not allow for tissue diagnoses or therapeutic intervention, a role that is still reserved for ERCP.

Management of benign disease

One of the most common uses for ERCP is treatment of biliary stone disease ([Figure 21.1](#)). Balloon extraction may be used for stone retrieval in combination with sphincterotomy, which allows for passage of stones and debris both during and for the period following the procedure. ERCP can also be used in the treatment of postoperative complications such as biliary strictures or leaks via sphincterotomy or stenting to relieve pressure in the biliary system. Strictures from chronic pancreatitis, primary sclerosis cholangitis, vasculitis, localized ischemic injury, etc., involving the extrahepatic biliary tree may also be treated with dilation, stenting, or a combination of both.^{5,6}

Management of malignant disease

ERCP is used for both diagnostic and therapeutic purposes in the setting of known or suspected malignant biliary disease. Cytologic brushings and biopsy forceps may be used to obtain tissue diagnoses.² Choledochoscopy, if available, may be used to facilitate sampling in more proximal biliary segments not accessible with standard ERCP techniques. Therapeutic applications of ERCP in the setting of malignant disease include stenting and balloon dilation of malignant strictures. Dilating balloons and biliary stents of various diameters are available for this purpose.⁷

DIAGNOSTIC TECHNIQUES

Tissue sampling

Tissue sampling methods include brushings and biopsy forceps. Current cytologic analyses using these methods, however, are associated with high specificity but low sensitivity in the differentiation between benign and malignant biliary

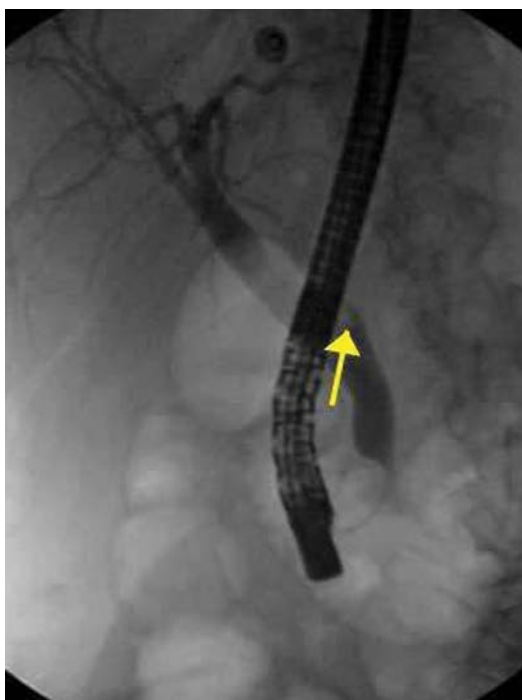


Figure 21.1 ERCP cholangiogram with yellow arrow showing a common bile duct stone.

disease.^{8,9} Recent advances in immunochemistry staining may improve the sensitivity of tissue sampling, but this continues to be a work in progress.¹⁰

Choledochoscopy

Choledochoscopy, performed using a separate smaller-caliber scope introduced via the working port of the duodenoscope, allows for visualization and collection of tissue samples from more distal biliary segments not accessible with standard ERCP. Traditionally, this mother-daughter system required an additional skilled endoscopist to operate the choledochoscope. A new development aimed to bypass the need for the additional endoscopist is the SpyGlass single-operator peroral pancreatoscopy system.^{11,12} The system uses a fiberoptic cholangioscope with a four-way dial attached to a standard duodenoscope that can be operated by a single skilled endoscopist. This, however, requires further skill and training of the performing endoscopist beyond that required for standard ERCP, and the scope itself may not be available in many endoscopic facilities.

THERAPEUTIC TECHNIQUES

Sphincterotomy

A sphincterotomy may be created as the primary therapeutic modality to relieve pressure in the biliary system and



Figure 21.2 Sphincterotomy creation.

promote outflow of biliary stones and debris. It also may be required to allow for other therapeutic interventions. The sphincterotome device is a specialized catheter with a bowed-wire cutting edge connected to an electrocautery current.¹³ Ideally, wire cannulation is achieved prior to sphincterotomy, but in cases where recurrent attempts at cannulation are unsuccessful, a pre-cut sphincterotomy may be performed to widen the papillary orifice and decrease the risk of postprocedural pancreatitis from further cannulation attempts (**Figure 21.2**).^{14,15}

Stone retrieval

The most common method for stone retrieval is via a standard extraction balloon available in sizes ranging from 8.5 to 20 mm diameters introduced over the cannulating wire.¹³ For larger stones unable to be removed with this technique, other options available include mechanical lithotripsy via a wire basket, extracorporeal shock wave lithotripsy, electrohydraulic lithotripsy (EHL), and laser lithotripsy.^{16,17} These techniques are limited by variable success rates that may require multiple sessions for adequate stone removal and expensive equipment that may not be readily available. In addition, EHL and laser lithotripsy require a choledochoscope. Each of these techniques is associated with its own unique complications including biliary injury, leakage, and cholangitis (**Figure 21.3**).

Stenting

For benign biliary disease, serial placements of multiple plastic stents may be used for stricture dilation. Plastic stents require exchanges every 3–4 months to maintain biliary



Figure 21.3 Balloon extraction of bile duct stones.

system patency and have a maximum size at 11.5Fr due to constraints of the duodenoscope working port. Plastic stents were traditionally preferred over metal stents due to ease of retrieval. Current literature suggest that fully covered self-expanding metal stents (SEMSs) may be a feasible alternative to plastic stents.^{5,18} Fully covered SEMSs have patency rates superior to plastic stents and are as easily retrievable but are more likely to migrate compared to using multiple plastic stents (**Figure 21.4**).

Unlike for benign disease, SEMSs are preferred for the treatment of malignant biliary strictures, particularly in patients with life expectancies longer than 4–6 months.¹⁹ SEMSs do not require sphincterotomy for placement, achieve larger diameters compared to plastic stents of up to 30Fr (10 mm) in size, and do not require frequent exchanges due to longer patency times.^{7,20} Uncovered SEMSs are less likely to migrate compared to fully covered SEMSs but are prone to tumor tissue ingrowth resulting in recurrent obstruction (**Figure 21.5**).²¹

Dilation

Biliary dilation may be performed with either balloons or rigid dilator systems introduced over a cannulating guide-wire. In cases of plastic stent placement, dilation may need to be performed first to allow for large-bore stent accommodation. Dilation is not usually required for SEMS placement. Dilation may be performed as the primary interventional procedure, but recurrence of stricture tends to be high without concurrent stent placement, except in certain cases, such as in primary sclerosis cholangitis.⁶ Dilation is contraindicated for fresh surgical anastomotic strictures less than 2 weeks old due to risk of suture line disruption.



Figure 21.4 Temporary plastic stent placed for benign biliary disease.



Figure 21.5 Covered SEMS placement for obstructive malignant lesion.

CONTRAINDICATIONS

Contraindications to ERCP include oropharyngeal or esophageal obstruction and anaphylactic reaction to contrast dye. Pharmacologic coagulopathy should be corrected prior to ERCP to prevent hemorrhagic complications. Portal hypertension with associated gastric or esophageal varices is a relative contraindication, and ERCP in those patients

should only be performed by extremely skilled endoscopists in high-volume centers.² Other relative contraindications to ERCP are similar to those for other invasive procedures, such as poor cardiopulmonary function.

COMPLICATIONS AND PREVENTION

ERCP is not without its own slew of complications including post-ERCP pancreatitis, bleeding, stent obstruction and infection, cholangitis, and more rarely, retroperitoneal perforation.² A general consensus is that high-volume centers that perform a large number of ERCPs have improved outcomes compared to low-volume centers.

The most common and variable complication is post-ERCP pancreatitis, and many studies have examined risk factors for postprocedural pancreatitis and possible preventative measures. Factors associated with increased risk of post-ERCP pancreatitis include difficult cannulation, pancreatic ductal contrast injection, pre-cut sphincterotomies, nondilated patient biliary system, sphincter of Oddi dysfunction, pancreas divisum, and prior pancreatitis.²

There has been significant debate regarding technical methodologies that may decrease the risk of postprocedural pancreatitis. Some data suggest that initial wire-guided cannulation decreases the risk of ERCP-related pancreatitis compared to contrast-directed cannulation.²² Wire-guided cannulation without contrast injection, however, runs the risk of possible pancreatic side-branch perforation in those in whom ductal anatomy is not straightforward.²³ Early placement of a small-caliber plastic pancreatic stent in high-risk patients may decrease the incidence of post-ERCP pancreatitis by protecting the pancreatic duct from injury while cannulation and sphincterotomy are attempted.²⁴

Pharmacologic interventions that have demonstrated some reduction in the incidence of post-ERCP pancreatitis include primarily periprocedural rectal indomethacin.^{23,25} Sublingual nitroglycerin is also of interest but by itself has not definitively proven to prevent postprocedural pancreatitis. Recently, a randomized control trial has found a potentially synergistic benefit of rectal indomethacin combined with nitroglycerin compared to indomethacin alone in the prevention of post-ERCP pancreatitis.²⁶

SURGICALLY ALTERED ANATOMY

In patients with surgically altered anatomy, ERCP is more technically challenging with higher failure rates, and several approaches have been developed in an attempt to surpass these difficulties. Single- and double-balloon enteroscopy have been applied to access the biliary tree in those with Roux-en-Y anatomy, though success rates are generally better with hepaticojejunostomies compared to gastric bypasses because balloon enteroscopy only utilizes a forward-viewing scope, and the biliary connection is more

direct with a hepaticojejunostomy.²⁷ Another method to facilitate successful ERCP in a gastric bypass patient that is out of the scope of this chapter is a combined laparoscopic and endoscopic approach via the gastric remnant, or trans-gastric access via an interventional radiology placed gastrostomy tube.²⁸

LIMITATIONS AND FUTURE DIRECTION

Some limitations of ERCP include the inability to access more distal sections of the biliary tree, but even then, new advances in choledochoscopy have made interventions more feasible in anatomic areas previously only addressed with open surgical techniques.

As new innovations to ERCP techniques arise and newer forms of endoscopic biliary intervention are refined, previously standard operations such as common bile duct explorations that were once the mainstays of surgical training are now increasingly rare.³ Further advancements in scope design, ancillary equipment development, and choledochoscopy will continue to drive endoscopic surgery to the forefront of biliary interventions.

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Endoscopy assistance in laparoscopic technique

MORRIS E. FRANKLIN JR. AND MIGUEL A. HERNANDEZ

INTRODUCTION

Advances in laparoscopic surgery have drastically modified this approach, and the tremendous success of the laparoscopic approach has led us to consider it as a tool in the management of abdominal surgery.

In the last 25 years, the minimally invasive surgery revolution has changed the way of facing abdominal disease issues. Worldwide there appeared more and more groups every day, documenting experience and different ways to perform minimally invasive surgery, using the traditional trocars of 5, 10, or 12 mm, trocars of 3 and 2 mm with instruments of the same size (acusopic surgery), single-port surgery. Also performed are intraluminal procedures such as gastric polyp resections, working inside of the stomach, or resections of colonic polyps combining the laparoscopic and endoscopic approaches, always attempting to be less traumatic with the body, giving the patient the advantage of quick recovery, return to routine, and work incorporation as well, making shorter the convalescence period and hospital stay, and even decreasing the total costs of the procedures.

The first instrument developed to look into deeper cavities was probably the rectal speculum; the earliest mention is found in Hippocrates' treaty on fistula. The ability to reflect light in deeply located organs was a central problem in designing open tubes to explore or retract tissues and allow the examiner to observe these structures.

Philipp Bozzini, one of the critical workers in the field, was born in 1773 in Mainz, Germany, an aristocratic Italian family. In principle, Bozzini's light guide consisted of a housing in which a candle was placed. On one side, he attached open tubes in various sizes and configurations that could be introduced into orifices, including the mouth and the rectum. Bozzini was one of the first inventors to insert a reflecting mirror between the visual tract and the candlelight, so that the light would be reflected only toward the organ and not into the examiner's eye. In 1807, when he

recommended the first prospective study of this device be performed in military hospitals, he received his first positive response. Gynecologists and ear, nose, and throat specialists expressed particular interest.¹

Some years later, in 1853, Antonin Jean Desormeaux described the open tube for examination of the genitourinary tract. He used a mixture of alcohol and turpentine as a light source. The beam was reflected into the tube. Desormeaux was the first to employ condenser lenses to increase the intensity of the illumination.

In the Egyptian and Greco-Roman time, the first successful rigid gastroscopy was reported in a sword swallower in 1868.¹

However, endoscopy was restricted to a small number of enthusiasts until 1932 when Schiendler and Wolf manufactured a semiflexible gastroscope in Germany. Subsequently, Schiendler migrated to the United States, promoted the safety and efficacy of gastroscopy, and was subsequently recognized as "the father of gastroscopy."¹ Other flexible endoscopes were also developed, although prior to 1965, they were only used by a relatively small number of individuals.

Dr. William Wolff and Dr. Hiromi Shinya pioneered the development of the colonoscope. Their invention in 1969 was an advancement over the barium enema and the flexible sigmoidoscope because it allowed visualization and removal of polyps from the entire large intestine.²

Interventional techniques began in 1939 when sclerotherapy of esophageal varicosities was first described, employing the rigid esophagoscope.³ It was not until the early 1970s when fiber optic technology emerged and Sugawa et al. described the endoscopic application of monopolar cautery.⁴ Other hemostatic techniques such as bipolar electrocoagulation, laser photocoagulation, heater probe, and endoscopic variceal band ligation evolved.^{5,6} Diagnostic endoscopic retrograde cholangiopancreatography and sphincterotomy,^{7,8} biliary stent placement,⁹ and removal of gastric polyps¹⁰ or small superficial gastric malignancies by snare

cauterization¹¹ constitute the most effective endotherapeutic maneuvers performed currently.

Sedillot performed the first open gastrostomy in 1849,¹² but it was not until 1981 that Ponsky and Gauderer described the technique of percutaneous endoscopic gastrostomy (PEG) in adults.¹³

Upper gastrointestinal endoscopy has been widely used in clinical practice for diagnosis and treatment in patients with upper gastrointestinal (GI) disorders. For diagnostic purposes, upper GI endoscopy is generally a safe procedure, with an extremely low (0.1%) rate of complication.¹⁷ Death rarely occurs in patients with underlying medical conditions, such as compromised cardiopulmonary function. Improvements in medical technology have resulted in the modification of modern endoscopes, making them feasible to introduce.

In 1991, Friemberger and Classen first described a pull-through trocar technique for percutaneous access to the stomach for the performance of intraluminal surgery. They used a metallic operative port 11.5 mm in diameter and 150 mm in length that was placed in a fashion similar to that of a PEG. Operative instruments introduced through the trocar permitted endoluminal gastric procedures.¹⁴

Laparoscopic-assisted intraluminal gastric surgery is a standard method for removing polyps from the stomach. Lesions located in the fundus, posterior body, and on the lesser curvature of the antrum may also be resected, although technical difficulties are often encountered. Ohashi et al. reported the first time in 1994^{15,16} "laparoscopic intraluminal gastric surgery" for the treatment of submucosal gastric tumors and early gastric cancer. One 10 mm and two 5 mm cannulas with a balloon on the tip of each were inserted directly into the gastric lumen after proper port position was determined by endoscopy. A nasogastric tube with a balloon was then placed in the duodenum, and the balloon was inflated to prevent CO₂ gas flow from the stomach to the small intestine. The resected area was left as a mucosal defect. No intraoperative or postoperative complications were discovered.

ENDOSCOPY TECHNIQUE

Blind insertion

In the blind insertion method, the endoscope is first passed over the base of the tongue toward the hypopharynx under external visual control. Care is taken that the endoscope tip is not retroflexed toward the nasopharynx and does not deviate to the left or right into the piriform recess. With proper technique, the instrument tip can be advanced just to the introitus of the upper esophageal sphincter, at which time the patient is instructed to swallow. Unless the patient swallows, it is extremely difficult to advance the endoscope through the upper esophageal sphincter without causing injury or significant discomfort. Endoscope insertion is contraindicated while the patient is coughing or taking a deep breath, as this will inevitably lead to tracheal intubation.

The period immediately after coughing, when the patient is swallowing saliva, is a favorable time for entering the esophagus. At this time, the larynx is in an elevated position, visible externally on the neck. Applying gentle pressure advances the endoscope. Following initial resistance, a distinct "give" is felt as the endoscope slips into the upper esophagus. Once the instrument tip is within the esophagus, the insertion is continued under endoscopic vision.

Direct-vision insertion

Esophageal intubation can also be performed under direct endoscopic vision. The instrument tip is advanced to the larynx as previously described. The open glottis aperture is seen. A slit can be identified between the posterior wall of the hypopharynx and the cuneiform and corniculate tubercles, which are clearly visible in most patients. This slit leads to the upper esophageal sphincter, which curves gently around the posterior side of the cricoid cartilage. The posterior wall of the larynx bulges far into the hypopharynx, making central passage difficult. The instrument tip should pass a little to the left or right of the midline, taking care not to deviate into either piriform recess. The instrument is advanced with gentle pressure until the patient swallows. The esophageal lumen becomes visible for a brief moment, and the tip is advanced into the esophagus. In many cases it is also possible to position the endoscope carefully at the esophageal introitus, have the patient swallow several times, and rotate the instrument into the esophagus. Care is taken not to slip into the piriform recess.

Technique problems

In both methods, blind and vision insertion, there is always a short segment of the esophagus that must be traversed without vision. If a Zenker diverticulum is present in this region, there is a substantial risk of perforation. If the endoscope is misdirected toward the trachea, the vocal cords or the typical ribbed walls of the trachea will be seen. In this case, the endoscope should be withdrawn at once.

COLONOSCOPY TECHNIQUE

A colonoscope can be inserted in two ways. The less artful, less technically demanding way is to push the colonoscope in without serious attempts to shorten the colon or straighten loops. This results in a relatively quick examination that can be completed for a majority of patients and is easy to learn. The more artful but technically demanding way to intubate the colon is to shorten it by removing loops as the colonoscope is inserted, thereby minimizing mesenteric stretch and maximizing patient comfort. Therapeutic maneuvers with a straight scope are easier and safer than when loops are present.

In our institute prior to using the colonoscope, we approach the patients laparoscopically. We mobilize the colon, isolate the small intestine coils, and the majority of the time there we identified the disease site. After these maneuvers we performed a colonoscopy, which is easier because the colon was freed, and we can move the colon to allow the colonoscope throughout the large intestine. We also use the colonoscope to do an anastomotic leak test, clamping the proximal side of the anastomosis, avoiding general intestinal distention, applying gas with the colonoscope and water from the intra-abdominal side, submerging the anastomosis site, and assessing the pneumatic anastomosis leak test.

COLONOSCOPY TECHNICAL CHALLENGES

A colonoscopic procedure consists of two phases: insertion and withdrawal. During the insertion phase, a flexible endoscope is advanced under direct vision via the anus into the rectum, and then gradually into the most proximal part of the colon or the terminal ileum. In the withdrawal phase, the endoscope is gradually withdrawn. The main purpose of the insertion phase is to reach the end of the colon, whereas in the withdrawal phase, careful inspection of all visible mucosa, tissue sampling, polyp removal, etc., are performed.

POSTOPERATIVE COURSE

As previously mentioned, offering the minimally invasive technique with the use of the endoscope that gives to the patient the opportunity of a faster recovery, less pain, shorter hospital stay, and less blood loss, decreases the dosage of pain medication and decreases the percentage of incisional hernias, thereby preserving the involved organ as much as possible. Since 1991 with the use of a hybrid

technique for difficult polyps in the large intestine named laparoscopic monitored colonoscopy polypectomy, with one of the biggest series around the world.

CONCLUSIONS

Since its development of endoscopy and colonoscopy, this tool has been widely used to screen, diagnose, and treat gastrointestinal diseases including cancer, facilitating the use of laparoscopic and intraluminal approaches together.

In this new era of minimally invasive surgery, it is mandatory that all surgeons learn to use the endoscope and colonoscope, which allows the greatest benefit of minimally invasive techniques.

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Natural orifice surgery



Gerald Marks, *MIS as the New Wave of Surgery*, 2017. Watercolor, 15 × 22 inches. (Image courtesy Dr. Gerald Marks.)

There are few surgeons who can be said to bridge the worlds of surgery and fine art. An internationally recognized colorectal surgeon and endoscopist, Dr. Gerald Marks, MD, has also distinguished himself as an accomplished self-trained watercolorist. For decades, he has created artworks based on his personal recollections of both his professional activities and leisure time, from cityscapes to landscapes, to his participation in worldwide surgical conferences and work in the operating room. Painted from photographs in his studio or en plein air, Dr. Marks renders form and light

through dashes of color and sweeping line. His style encapsulates the fleeting essences seen in impressionist paintings of the nineteenth century.

This scene shows a team of surgeons clad in blue gowns performing a minimally invasive surgery. Dr. Marks has centered the action on the operating table, focusing on the ability of the team to work in tandem to complete the procedure. The suspended flood lights above illuminate the scene, which falls out of view and becomes abstracted beyond the surgeons' field of vision. The sketch-like quality

of Dr. Marks's brushstrokes record his impressions of the activities of the surgeons, while still attending to the details of this innovative technique.

Each year, Dr. Marks produces a calendar from a selection of his paintings through the Marks Colorectal Surgical Foundation, which promotes research and educational programs related to colorectal disease. The foundation also supports a Fellowship in Laparoscopic Colorectal Surgery and Minimally Invasive Transanal Endoscopic Microsurgery of the Rectum, the Video Library of Minimally Invasive

Surgical Procedures, and the Operating Room Preceptor Program. Dr. Marks is a professor of surgery at the Lankenau Institute for Medical Research and a practicing colorectal surgeon with his son, Dr. John Marks, at the Lankenau Hospital in Wynnewood, PA. He is renowned for his contributions in flexible colonoscopy, the management of radiation injuries of the intestines, and rectal cancer management with sphincter preservation.

This image was used as the poster for the 2017 SAGES meeting and the World Congress of Endoscopic Surgery.

Transvaginal access for natural orifice transluminal endoscopic surgery

KURT ERIC ROBERTS AND STEPHANIE G. WOOD

INTRODUCTION

History

Since natural orifice transluminal endoscopic surgery (NOTES) has established its feasibility and safety in modern-day surgery, the majority of surgeons who perform NOTES procedures today access the abdominal cavity through the vagina.

Historically, the earliest predecessor of transvaginal (TV) access for NOTES was TV culdoscopy. Performed since the late 1800s to visualize pelvic and intra-abdominal organs, the Russian surgeon Dimitrij Ott was the first to describe the procedure in 1902.¹

In 1937, the Austrian surgeon Emanuel Klatfen presented a TV culdoscopy technique for diagnostic and limited operative procedures.^{2,3}

In the United States, TeLinde was recognized for performing one of the first TV culdoscopies in 1940.^{4,5}

In 1942, Albert Decker invented what is today known as the Decker culdoscope, a rigid instrument with a lamp adjacent to a lens at the distal end.^{6,7}

In the late 1960s and early 1970s, TV culdoscopy was combined with fiberoptics and began to flourish as a diagnostic and therapeutic procedure.⁷⁻¹⁰ Commonly performed under local analgesia,^{7,8} it was mainly utilized for infertility evaluations.¹⁰

In 2001, Tsin reported a feasibility project in which 13 patients underwent laparoscopic-assisted TV culdoscopy, which he coined as culdolaparoscopy.¹¹ He performed selected gynecologic procedures including oophorectomies, myomectomies, salpingo-oophorectomies, and one salpingectomy.

In 2005, Gordts et al. described TV laparoscopy as a combination of culdoscopy and TV hydrodistension.

More recently, in 2007, Tsin et al. published a collective review of 100 TV culdolaparoscopic cases referred to as Minilaparoscopy-Assisted Natural Orifice Surgery (MANOS).¹² Multiple operative procedures were reported including salpingo-oophorectomy, myomectomy, ovarian cystectomy, appendectomy, and cholecystectomy during TV hysterectomy.

INDICATIONS/CONTRAINDICATIONS

Indications and contraindications for TV access in NOTES procedures are similar to laparoscopic or open access procedures and mainly determined by specific patient characteristics and surgeon experience.

Current absolute and relative contraindications for TV access in NOTES are as follows ([Table 23.1](#)):

1. *Size of Uterus/Retroverted Uterus*: Size of the uterus, presence of uterine fibroids or a retroverted uterus are relative contraindications to TV NOTES.

Table 23.1 Contraindications for TV NOTES access

Size of uterus/retroverted uterus
Prior hysterectomy
Pelvic inflammatory disease/endometriosis
Narrow vagina
Prior abdominal surgery
Vaginal infection
Virginity
Postpartum period
Obesity
Inflammatory bowel disease
Dyspareunia

2. *Prior Hysterectomy*: Patients with prior hysterectomy or previous pelvic surgery might be considered a contraindication to TV NOTES because of the possible failure of TV access secondary to pelvic adhesions.¹³
3. *Pelvic Inflammatory Disease or Endometriosis*: Patients with a history of pelvic inflammatory disease or endometriosis have a high probability of pelvic adhesions and are therefore an exclusion criteria for TV NOTES.
4. *Narrow Vagina*: Lack of accessibility of the vaginal passageway (narrow vagina less than two fingerbreadths especially at the uterine apex) is a technical contraindication to TV NOTES.
5. *Prior Abdominal Surgery*: Prior abdominal surgery in itself should not be considered a contraindication to TV NOTES. It depends on the expertise and comfort level of the surgeon to proceed.
6. *Vaginal Infection*
 - a. Vaginal infections discovered at the preoperative visit should be treated with the appropriate antibiotic treatment prior to surgery.
 - b. If a vaginal infection is discovered on the operating room table, it will depend on the intraoperative findings whether it is advisable to proceed with a TV NOTES procedure or not. True mucopurulent cervicitis, cervicitis/endometritis, suppurative vulvar lesions, like Bartholin gland abscess and active hidradenitis suppurativa, should be treated, and the TV access should not be performed. However, yeast vaginitis and yellow vaginal discharge without cervical exudate do not constitute sufficient evidence for the presence of a virulent pelvic pathogen and should not prompt the cancellation of a TV NOTES procedure.
7. *Virginity*: TV NOTES is technically possible in patients with an intact hymen, and vaginal hysterectomies have been previously described in virgin women.¹⁴ In our opinion, TV surgery should only be performed if the woman is clearly informed that the hymen will likely not be intact after surgery, and she still wishes to proceed with TV surgery.
8. *Postpartum Period*: The process by which the uterus and the other genital organs return to their normal prepregnant state in the postpartum period takes 6 weeks. Therefore, we recommend avoiding TV NOTES for at least 6 weeks after delivery.
9. *Obesity*: Certain groups of surgeons consider obesity a contraindication to TV NOTES procedures.^{15,16} The labial adipose tissue may make retraction and access to the posterior vaginal fornix more difficult during initial trocar insertion or culdotomy closure.
10. *Inflammatory Bowel Disease*: There is evidence that patients with Crohn's disease/ulcerative colitis can develop enteric vaginal fistulae, and therefore we recommend avoiding TV NOTES in patients who suffer from Crohn's disease or ulcerative colitis.

11. *Dyspareunia*: Patients who describe dyspareunia prior to an offered TV NOTES surgery should undergo a traditional laparoscopic approach, because the TV approach could worsen the pain.

PERIOPERATIVE CONSIDERATIONS

Antibiotic prophylaxis

TV NOTES surgeries are classified as clean-contaminated cases. Cephalosporins have emerged as the drugs of choice for most operative procedures because of their broad antimicrobial spectrum and low rate of side effects.

Patient positioning

Trendelenburg positioning is the generally preferred patient positioning for TV NOTES procedures. To prevent sliding of the patient, we recommend the use of a gel mattress, egg-crate, or beanbag devices directly in contact with the patient's back without any overlying sheet to create a high friction coefficient. Shoulder pads and additional safety measures should also aim to avoid sliding of the patient.

Vaginal preparation

Povidone-iodine surgical preparation is the most commonly employed method in vaginal vault preparation for a vaginal surgery. Alternatively, a 4% aqueous chlorhexidine gluconate solution may also be appropriate as the vagina is lined by an epithelial surface and not by a vaginal mucosa.

POSTOPERATIVE CONSIDERATIONS

Generally, patients should avoid placing anything inside the vagina until the vaginal incision is well healed. Most surgeons recommend avoiding intercourse for 2–4 weeks following surgery. A speculum and bimanual exam may be performed before lifting these restrictions. Many experts recommend pre- and post-operative use of estrogen cream or tablets within the vagina for at least 7 days to promote local healing in postmenopausal women.

TV NOTES is commonly performed in women with intrauterine devices. If accidentally removed or dislodged during the surgery, it should be replaced following conclusion of the TV NOTES procedure.

ACCESS TECHNIQUES

Entry into the cul-de-sac can be performed in steep Trendelenburg with the patient either in genupectoral position^{4,17} or dorsal decubitus position.^{18,19} A speculum or retractor is inserted into the vagina to expose the posterior fornix and to visualize the cervix. A tenaculum is placed

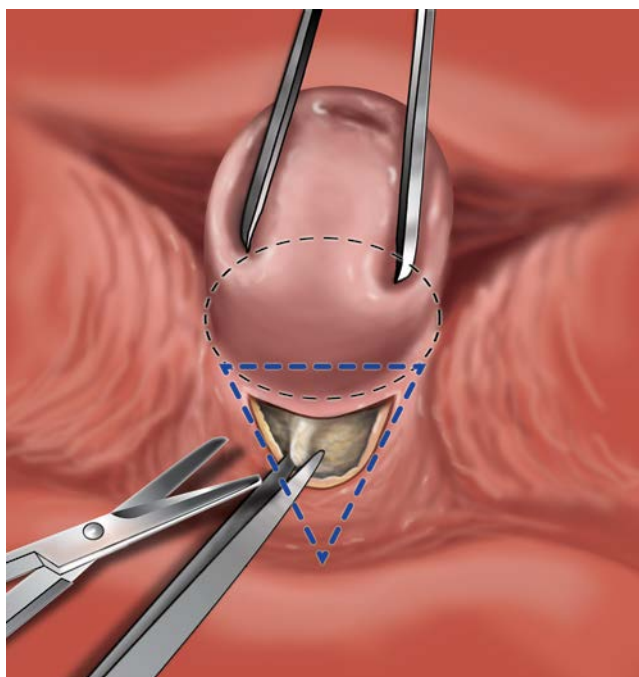


Figure 23.1 The Triangle of Safety. The colpotomy is made within the depicted picture upside down equilateral triangle that dissects the elliptical circle, marking the base of cervix, at 4 o'clock and 8 o'clock.

on the posterior lip of the cervix, which is placed on traction in order to identify the cervicovaginal junction and the outline of the uterosacral ligaments. Alternatively, a uterine manipulator can be inserted into the cervical os.

The safest area to enter the abdomen within the posterior fornix was described in 2012 by Roberts et al. as the “Triangle of Safety”²⁰ (Figure 23.1).

After the cervix and posterior fornix are visualized, a clock located at the base of the cervix is envisioned (Figure 23.2a). The superior two corners of the triangle mark the 4 o'clock and 8 o'clock positions. Sometimes the cervix needs to be grasped and elevated anteriorly, so that the inferior apex of the triangle delineated by the center of the rectovaginal fold can be easier visualized. Similarly, on the internal (umbilical) view of the Triangle of Safety, the uterosacral ligaments mark the two upper corners, and the center of the rectovaginal fold marks the inferior corner of the Triangle of Safety. Within this triangle, the port is angled toward the umbilicus (Figure 23.2b).

INSUFFLATION

Insufflation of the peritoneal cavity is commonly performed with a Veress needle placed in the umbilicus or the abdominal wall. Alternatively, TV insufflation can be achieved with a Veress needle placed in the posterior cul-de-sac or through a transvaginally placed port. Transuterine insufflation is only recommended if the

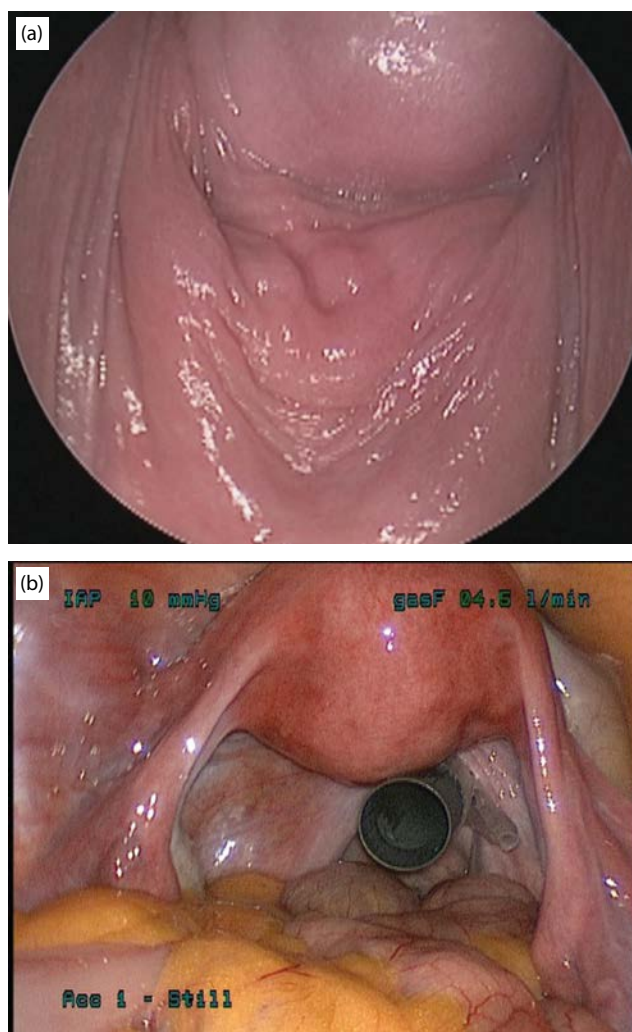


Figure 23.2 (a) Vaginal view of the Triangle of Safety. (b) Umbilical view of the pelvis with the 12 mm port placed within the Triangle of Safety.

surgeon is experienced with this specific technique. If a flexible endoscope is used, insufflation can be established through one of the working channels.

VAGINAL ACCESS PORTS

A wide variety of different ports and systems are currently used for TV NOTES (Table 23.2). We recommend laparoscopic pelvic visualization from the umbilicus (Figure 23.2b), because it is a very reliable method to identify possible adhesions and contraindications and avoid rectal and bowel injury during vaginal entry and placement of the vaginal access port.

CLOSURE TECHNIQUES

Most NOTES surgeons recommend closing the colpotomy with absorbable suture in either an interrupted or running fashion under direct visualization (Figure 23.3).

Table 23.2 Examples of ports and port systems used in TV access NOTES

Custom-made vaginal port—Davila et al. ³⁵
GelPort (Applied Medical, Rancho Santa Margarita, California) ³⁶
Incisionless Operative Platform (USGI Medical, San Clemente, California) ³⁷
NOTES GEN1 Toolbox (Ethicon Endo-Surgery, Inc., Cincinnati, Ohio) ³⁸
Regular 12-mm ports—Roberts et al. ³⁹
SILS Port (Covidien, Norwalk, Connecticut) ³⁹
Surgical Glove—Sohn et al. ⁴⁰
TriPort (Advanced Surgical Concepts, Ireland) ⁴¹
Vaginal Access System (Karl Storz, Tuttlingen, Germany) ¹³



Figure 23.3 Vaginal view of TV running closure of a pure TV appendectomy.

COMPLICATIONS

Today, there are over 3,000 human cases of TV endoscopic procedures performed with an overall complication rate of around 5% (**Table 23.3**).

Complications for TV NOTES include the following:

1. **Infection:** Although infections have been a concern from the very beginning of TV NOTES, occurrence rates in the gynecologic literature have always been low and are even lower in the TV NOTES literature.
We reviewed the first reported thousand cases in the literature and found only two infectious complications. One of them involved a pouch of Douglas abscess after a hybrid TV cholecystectomy, and the second infectious complication was an abscess in the right lower quadrant at the appendectomy site after a TV appendectomy for gangrenous appendicitis. Both complications were successfully treated.

Table 23.3 Potential complications related to TV access in NOTES

Infection
Rectal injury
Bladder injury
Vaginal wound dehiscence
Vaginal granulation tissue
Vaginal bleeding
Urinary tract infection
Dyspareunia

2. **Rectal Injury:** Rectal injuries during TV procedures occur infrequently and can often be treated nonoperatively.

In 2001, Gordts et al. published a multinational retrospective survey of 3667 self-reported cases in the gynecological literature. The study reviewed the risk of bowel injury associated with culdoscopy using a Veress needle-trocar system.²¹ Twenty-four full-thickness bowel injuries occurred resulting in an overall incidence of 0.65%. Of the 24 rectal injuries reported, all were lesions measuring 2–6 mm, and 92% of patients underwent successfully expectant management. In the other 8% of patients, surgical repair was performed.

Within the TV NOTES literature, two cases of rectal injury have been described. One was successfully treated nonoperatively, and in the second case a transrectal closure of the injury was performed successfully.²²

3. **Bladder Injury:** Occurrence rates for bladder injuries are low. Agostini et al. reported 0.89% bladder injuries during vaginal hysterectomies.²³

The German D-NOTES registry describes four bladder injuries associated with TV access.²⁴ One bladder injury required intraoperative laparoscopic sutures, and two others were managed with an indwelling catheter.

Visualization of the pelvis from the umbilicus and an indwelling bladder catheter may be useful in reducing the risk of a bladder injury even further.

4. **Vaginal Wound Dehiscence:** There have been no reports of dehiscence or evisceration in the TV NOTES literature.

Closure of the vaginal wound is generally performed externally under direct vision using absorbable sutures and conventional instruments.

In a gynecological review that included 13,030 endoscopic hysterectomies, 0.66% of postoperative vaginal separations occurred. Vaginal dehiscence was lower for TV cuff closure (0.18%) than for both laparoscopic (0.64%) and robotic (1.64%) colpotomy closure.

Vaginal dehiscence will most likely remain a very rare complication, since the vaginal incision is significantly smaller compared to hysterectomies. The uterus may add additional protection if present in TV NOTES patients.

5. **Vaginal Granulation Tissue:** Only two cases of vaginal granulation tissue following a colpotomy closure have been reported in the TV NOTES literature.^{13,22} In contrast, it is commonly reported in the gynecology literature ranging in frequency from 1.27% to 34% for TV hysterectomy vaginal incisions.^{25,26} These patients are typically managed conservatively with an occasional need for chemical cauterization with one or two silver nitrate applications to the granulation tissue.
6. **Vaginal Bleeding:** Vaginal bleeding is a rare event that occurs typically in the first 2 weeks after surgery. It is usually self-limited and rarely requires readmission or reintervention.^{13,24}
The most common sources for bleeding are from insufficient closure at the vaginal incision site, an unintended vaginal mucosa tear from instruments, and bleeding from the cervix if a tenaculum was used. Menstruation may occur early due to the vaginal instrumentation leading patients to think that they experience surgical bleeding. Some spotting for 1–3 days after surgery is not uncommon.
7. **Urinary Tract Infection:** In a review of vaginal hysterectomies, a rate of 0.68% of urinary tract infections was encountered.²⁷ This is comparable with the number of urinary tract infections in the TV access for NOTES patients. Standard meticulous sterile technique should be used when placing an indwelling catheter.
8. **Dyspareunia:** There is only one case report of dyspareunia after TV NOTES procedures in the literature.²⁸ Others have reported that female sexual function is not impaired after TV procedures.^{29,30} However, data in gynecologic literature remain controversial. The TV approach to hysterectomies has been demonstrated not to affect sexual outcomes in a number of studies,^{31,32} but others reported dyspareunia after vaginal hysterectomy.²⁸ Some studies report that female sexual function and dyspareunia improved after hysterectomy.³³

TRAINING AND CREDENTIALING

There are currently no relevant studies or recommendations concerning the training and credentialing of TV access for NOTES. In the absence of a clearly defined learning curve, didactic lectures on anatomy, indications, and complications represent essential training requirements for TV access surgeries. In addition, prior to performing a TV NOTES on a patient in the operating room, surgeons should have dedicated didactic lectures on the technique and practice on a trainer or simulator³⁴ (Figure 23.4). Most general surgeons acquainted with TV NOTES recommend that the first 5–10 colpotomies for NOTES by surgeons unfamiliar with the technique should be performed under the supervision of an experienced gynecologist or surgeon in order to minimize adverse outcomes.



Figure 23.4 V-NOTES simulator at NOSCAR (Natural Orifice Surgery Consortium for Assessment and Research) meeting.

CONCLUSION

TV access has been used for over 100 years for many gynecologic procedures. It is well accepted and represents the standard of care. Historic and present reports from the gynecologic literature strongly support the safety and feasibility of the TV approach.

Today, the TV approach has established its feasibility and safety in a large number of NOTES procedures performed around the world. Complication rates are low and similar to traditional laparoscopy. To date, there are no reported deaths related to the TV NOTES access. Special consideration must be given to patient selection and contraindications, as well as the specific technical requirements.

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Percutaneous endoscopic gastrostomy

JEFFREY L. PONSKY AND AVERY C. CAPONE

It is approaching four decades since the concept of percutaneous endoscopic gastrostomy was first introduced. This simple technique combined endoscopy and surgical problem solving to achieve a minimally invasive approach to enteral access. Although variations and modifications of the method have evolved over the years, the basic concept and approach to the procedure remain unchanged. In retrospect, the introduction of this method was one of the first forays into the era of minimally invasive surgery.

INDICATIONS

Percutaneous endoscopic gastrostomy (PEG) was initially introduced to provide a minimally invasive means to establish enteral access for feeding¹ in those with severe neurological impairment, oropharyngeal neoplasia, and esophageal obstruction. While this remains the predominant indication for the procedure, PEG has also been used to provide gastric decompression in patients with carcinomatosis² and those with complicated bowel obstructions due to adhesions, gastric atony, or inflammatory bowel disease.³ In combination with jejunal extension tubes⁴ or direct jejunostomy,⁵ gastric decompression may be achieved in combination with jejunal feeding.

PEG has been used to deliver supplemental feedings to malnourished patients as well as to deliver unpalatable medications. The method has been applied to intragastric surgery⁶ and after reduction of gastric volvulus as a means of anchoring the stomach below the diaphragm.⁷ In the colon, the technique has been applied to the reduction of sigmoid volvulus^{8,9} and in the cecum to decompress Ogilvie syndrome.¹⁰

TECHNIQUES

The original description of PEG presented the “Pull” technique¹¹ (Figure 24.1). This method is still the most widely

used today. Prior to the procedure, prophylactic intravenous antibiotics, usually a cephalosporin, are administered to reduce the incidence of abdominal wall infections. Upper endoscopy is performed, and a site is chosen for gastric puncture. Although the original description of the method relied on transillumination of the abdominal wall by the light of the endoscope (Figure 24.2), other methods for the localization of the optimal gastrostomy site include finger indentation (Figure 24.3) and the Safe Tract technique¹² (Figure 24.4). In this method, a needle attached to a fluid-filled syringe is slowly advanced across the abdominal wall at the site deemed best by finger pressure. Bubbles should appear in the barrel of the syringe at exactly the same moment that the needle tip is visualized endoscopically within the gastric lumen. If bubbles are seen in the syringe before the needle tip appears in the stomach, there is likelihood that the needle has breached another organ such as the colon or small bowel. In this case, the needle is removed and another site chosen for puncture.

Once the site is selected, a snare is passed through the endoscope and opened over the selected site. A tiny incision is then made at the selected site on the abdominal wall, and a larger needle is then passed into the gastric lumen into the waiting snare loop. The snare is then closed around the puncturing needle. A looped, wire suture is passed through the puncturing needle into the stomach. The endoscopic snare is loosened from around the needle and re-secured around the wire suture. The scope and the suture are then pulled out of the patient’s mouth. The suture is then affixed to the end of the gastrostomy tube. The operator at the abdominal position then pulls the suture at the abdominal wall. The aft end of the gastrostomy tube is then pulled down into the esophagus. The mushroom head of the catheter may be held with the endoscopic snare so that the scope may easily follow the tube into the stomach. Once the gastroscope is in the esophagus, the snare may

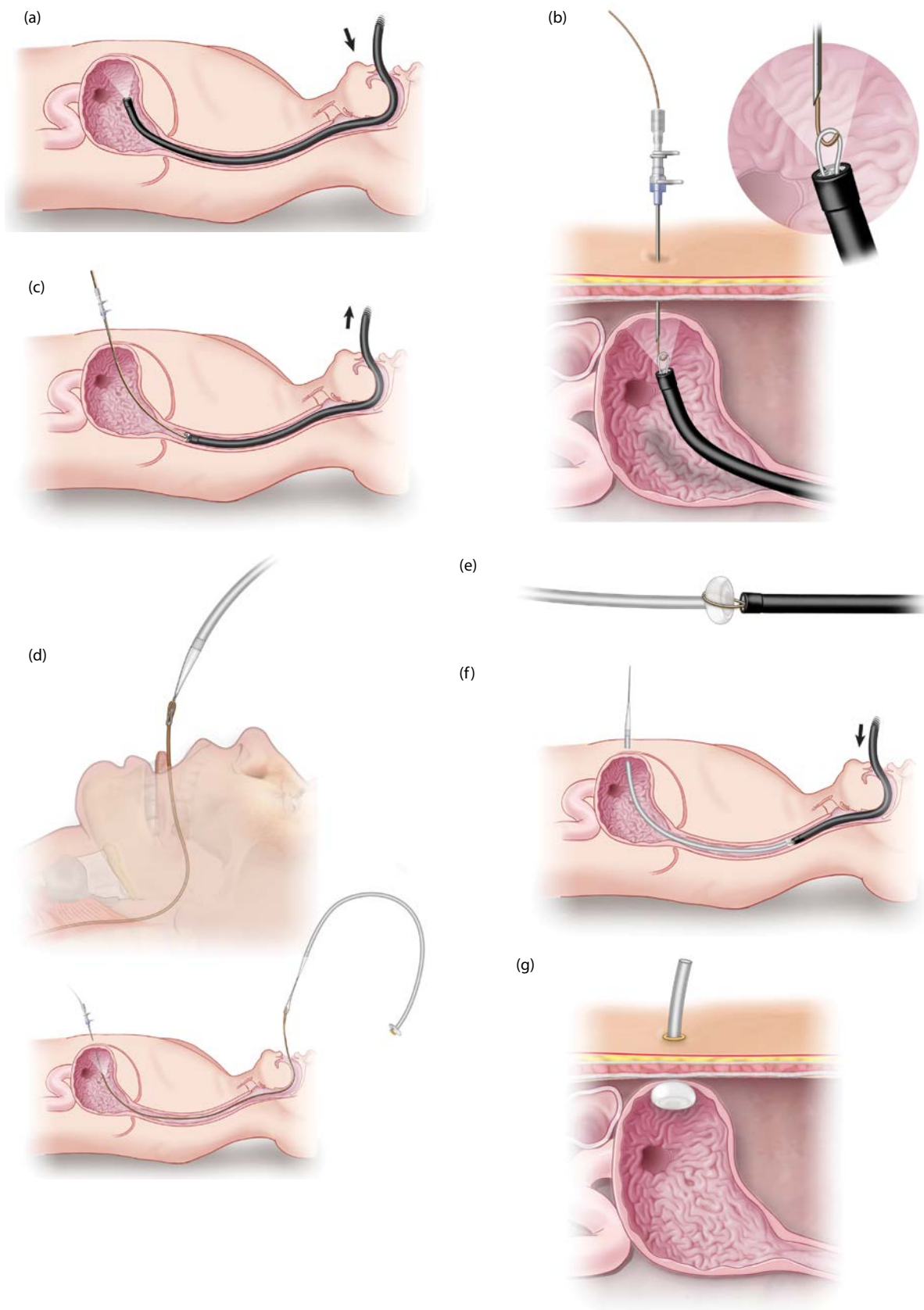
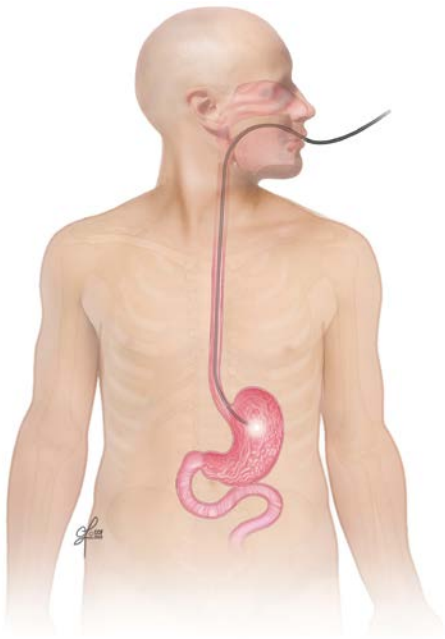


Figure 24.1 The "Pull" technique for PEG. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

(a)



(b)

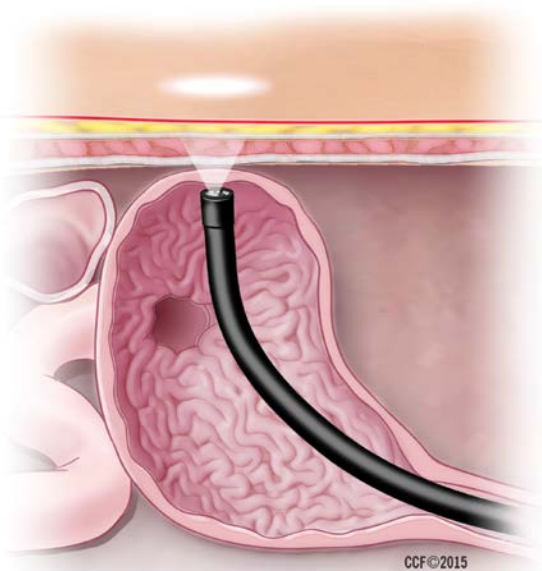
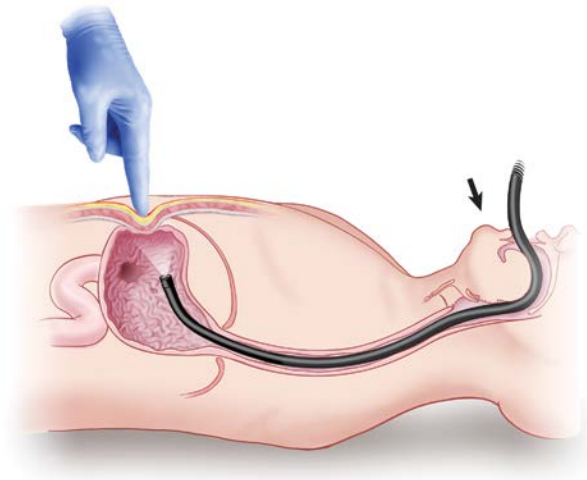


Figure 24.2 Transillumination technique for gastrostomy localization. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

(a)



(b)

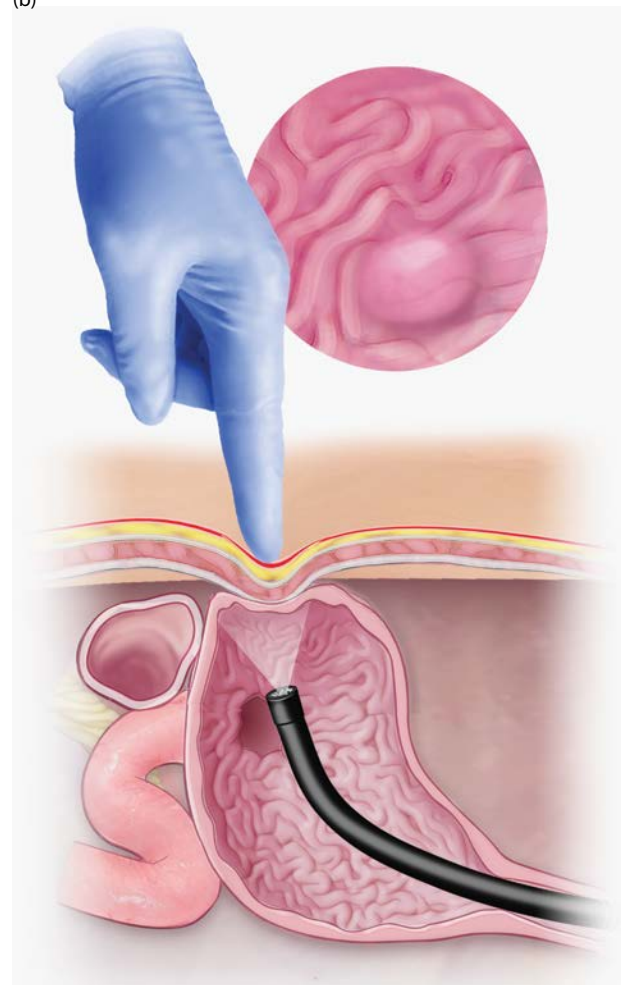


Figure 24.3 Finger indentation technique for gastrostomy localization. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

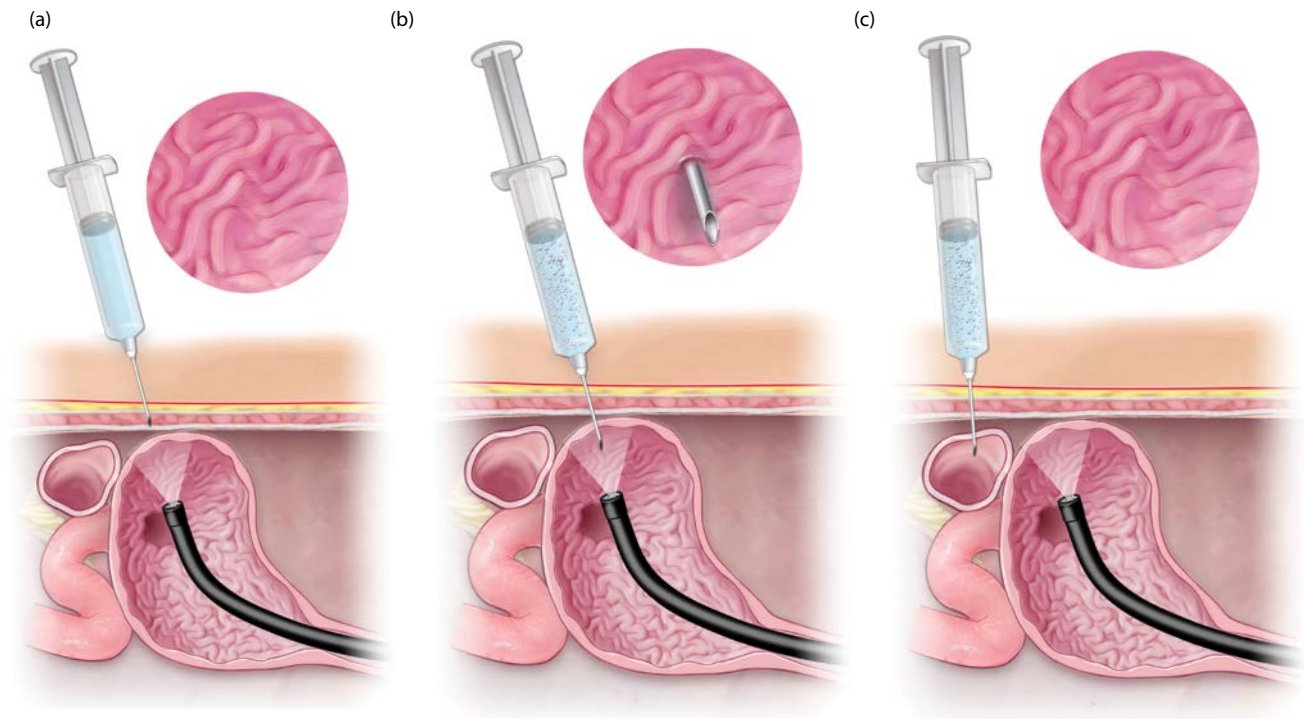


Figure 24.4 The Safe Tract technique for gastrotomy localization. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

be released from the head of the catheter. The tube is then pulled into the stomach until the mushroom head of the catheter lies in contact with the gastric mucosa. An outer crossbar or bumper is affixed to the gastrostomy tube and positioned several millimeters from the skin to avoid skin compression and resultant ischemia.

Alternative methods for placement of the tube have included the “Push” technique (Figure 24.5) and the “Introducer” technique (Figure 24.6). In both instances, the site for gastric puncture is selected in the same manner. In the “Push” method, a guidewire is passed into the waiting snare loop and pulled out of the stomach through the mouth.¹³ The gastrostomy tube is then advanced over the guidewire in a Seldinger technique, then pushed down the esophagus, into the stomach, and out of the abdominal wall.

The “Introducer” technique¹⁴ and modifications of the method such as the “SLiC” procedure¹⁵ (Figure 24.7) have been particularly valuable in patients with oropharyngeal tumors, where previously described techniques may spread malignant cells and seed the abdominal wall with tumor.^{16,17} In this approach, a gastrotomy site is selected, and the stomach is punctured through the abdominal wall. The site is dilated and a tube is inserted over a short guidewire under endoscopic visualization. Some individuals have described placement of T-fasteners adjacent to the tube in order to secure the approximation of the stomach and the abdominal wall^{18,19} (Figure 24.8).

COMPLICATIONS

Common complications of the PEG procedure include infections of the skin and abdominal wall around the tube as well as migration of the tube through the abdominal wall with early extrusion.²⁰ Most of these complications are due to excessive tension placed on the crossbar at the skin level, creating ischemia and necrosis of the abdominal wall with resultant infection and extrusion of the catheter head. It is recommended that the outer crossbar remain several millimeters from the skin to avoid such problems.^{21,22} Also, it has been demonstrated that preprocedural prophylactic antibiotics are beneficial in preventing peritubal infections.²³ The administration of antibiotics, such as a cephalosporin, has become the standard of care.

Introduction of the Safe Tract technique has reduced but not eliminated the possibility of puncture of an organ adjacent to the stomach. Puncture of the colon²⁴ and small bowel²⁵ have been documented in performance of a PEG. Gastrocolic fistula may be noted immediately or after many months. In the latter case, the fact that the tube traversed the colon may only become apparent when the tube is exchanged. The replacement tube’s head comes to reside within the colon producing diarrhea with feeds.^{26,27} Such fistulas usually close spontaneously with removal of the PEG tube.

To minimize such injuries to adjacent viscera, the Safe Tract method must be performed slowly, introducing the

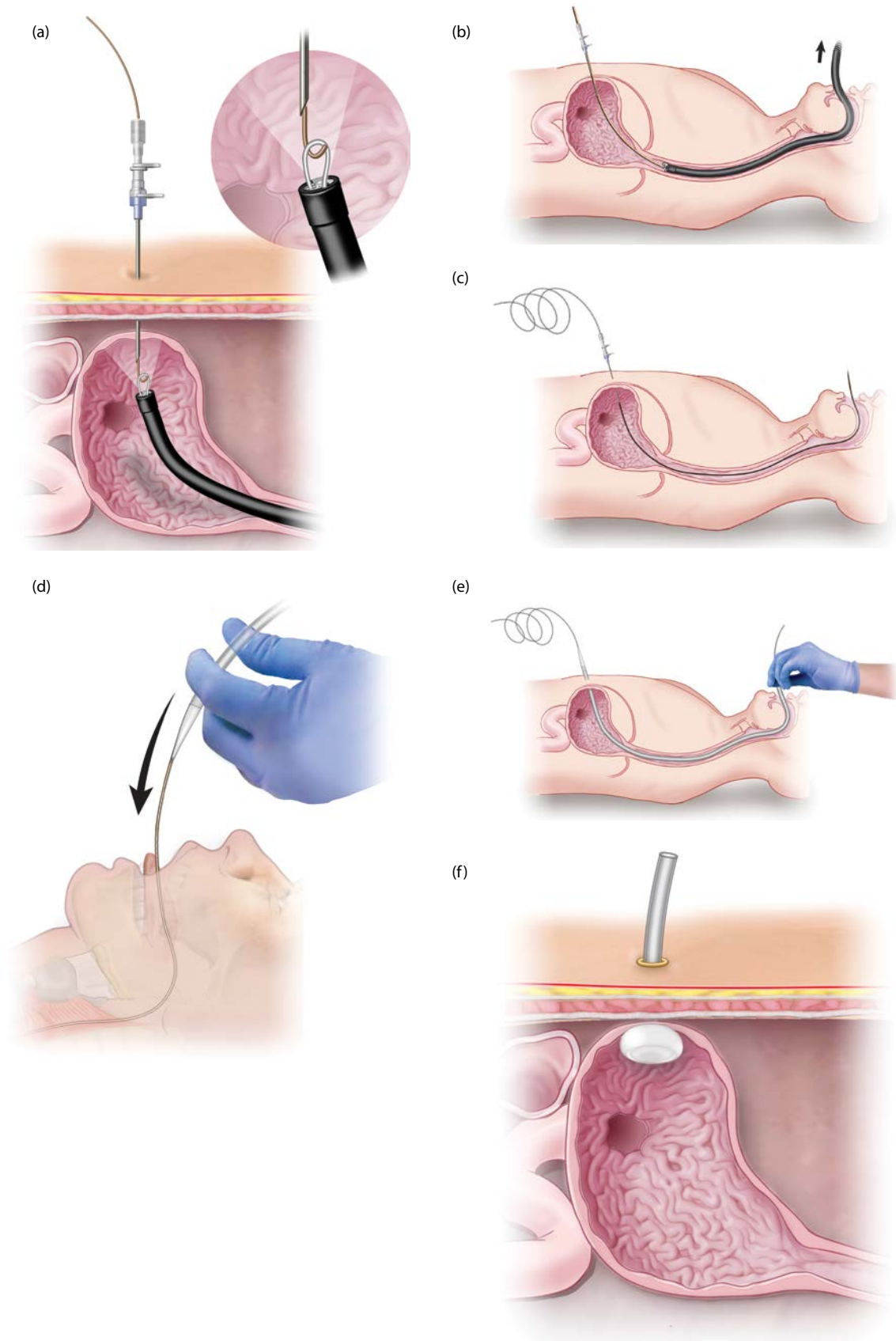


Figure 24.5 The “Push” technique for PEG, also known as the Sachs-Vine technique. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

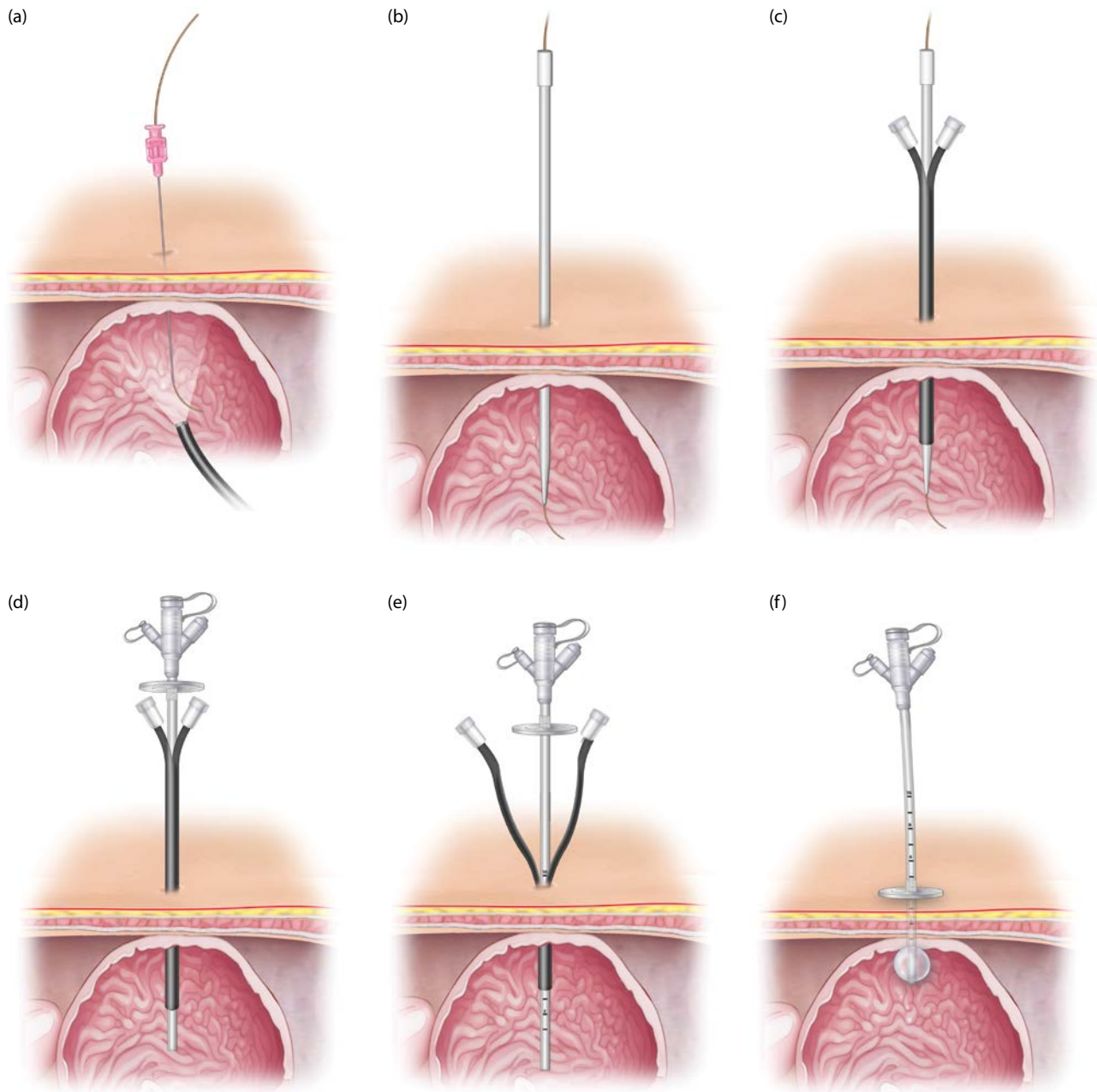


Figure 24.6 The "Introducer" or direct technique for PEG, also known as the Russell technique. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

needle into the abdomen a few millimeters at a time while aspirating on the barrel. Any suggestion of air in the barrel prior to seeing the needle endoscopically in the gastric lumen should prompt selection of another site.

MODIFICATIONS OF THE METHOD

Adaptations of the original PEG technique have been developed for specific purposes. Patients with abnormal gastric

emptying may be treated with jejunal feedings on a short- or long-term basis. When such a situation is deemed to be relatively short lived, the PEG tube may be modified to carry a longer jejunal extension tube (PEG-JET) (Figure 24.9). In such situations, a smaller feeding tube is placed through the lumen of the PEG tube or parallel with it, and is then placed into the duodenum or jejunum. The gastric tube is used for decompression, while feedings are delivered through the smaller, distal jejunal tube. This method, originally described in the 1980s,⁴ may be effective in the short term

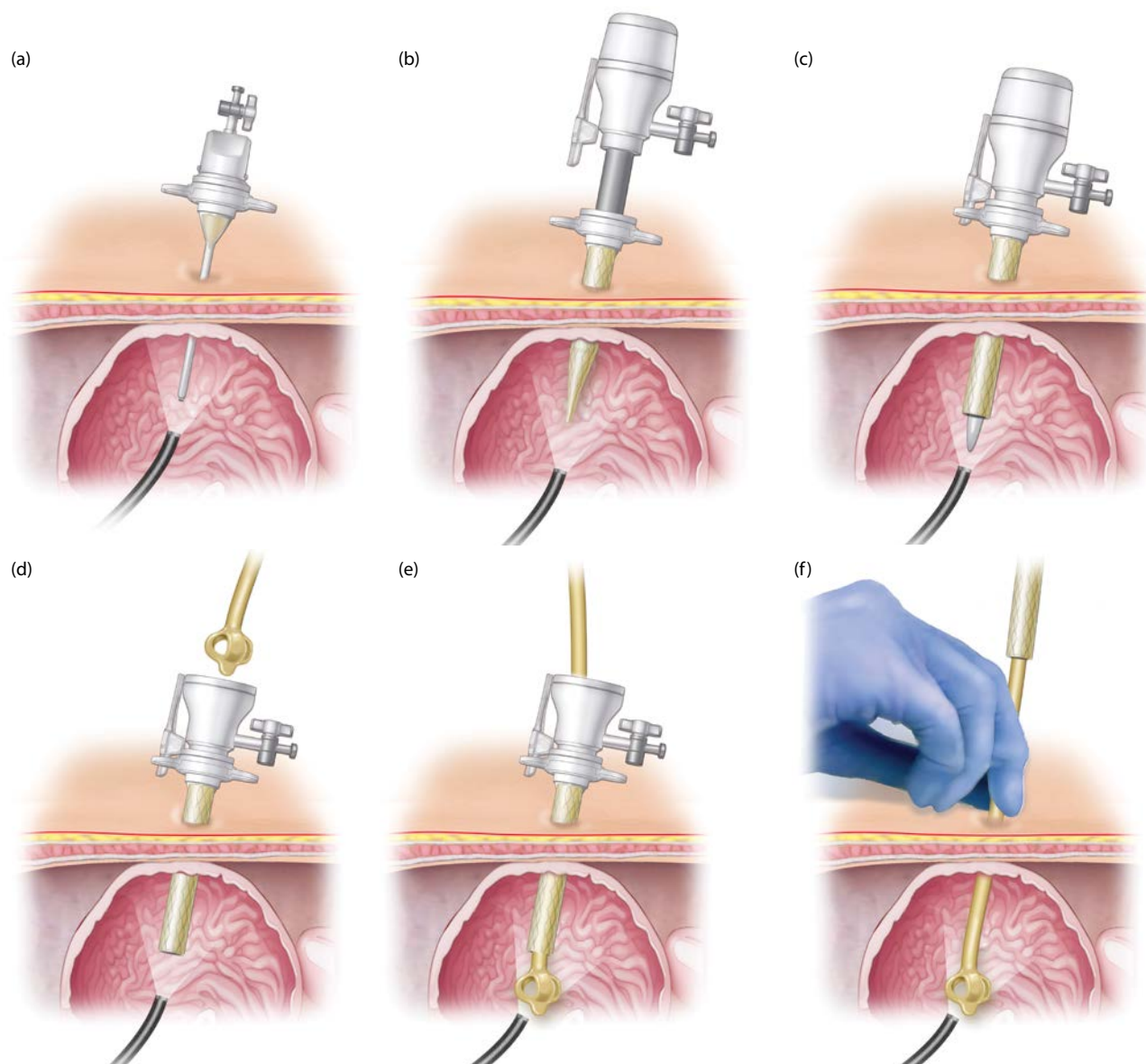


Figure 24.7 The SLiC technique for PEG, a modification of the "Introducer" technique. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

but is often challenged by clogging of the jejunal tube or migration of the jejunal tube back into the stomach. In many cases, frequent adjustments of the system are necessary.

When the necessity for long-term jejunal feeding is anticipated, a direct percutaneous endoscopic jejunostomy (PEJ) may be performed. In such cases, a PEG-type tube is placed distal to the ligament of Treitz by the same method as a gastric PEG.⁵ A pediatric colonoscope or enteroscope is used to access the jejunum, and the use of the Safe Tract method is of paramount importance in preventing inadvertent puncture of an adjacent loop of bowel. In such cases, a traditional PEG tube may be placed into the stomach for decompression while the PEJ tube is used for feeding.

FUTURE DIRECTIONS

The techniques of minimally invasive enteral access for feeding or decompression have changed little since their original description. Creative modifications of the techniques have been developed to suit specific situations. Still, placement of jejunal extension tubes often remains a frustrating experience,²⁸ and new tubes must be developed to facilitate this process. Tubes specifically designed to decompress the stomach may also be developed. Creative adaptations of the PEG technique have arisen for intragastric surgery, gastric and sigmoid volvulus reduction, and colonic decompression. It is likely that future uses of the concept of direct enteral access will continue to emerge.

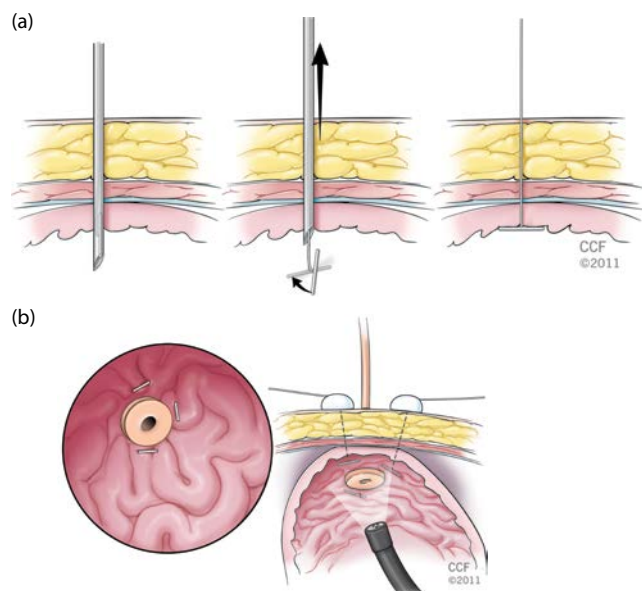


Figure 24.8 The T-fastener method for stomach and abdominal wall approximation. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

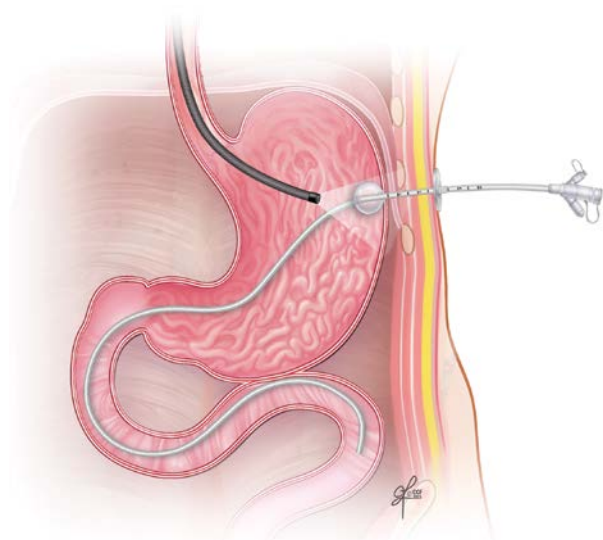


Figure 24.9 Gastrostomy tube with jejunal extension (PEG-JET tube). (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2015. All Rights Reserved.)

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Peroral endoscopic myotomy (POEM) for achalasia

PAUL COLAVITA AND LEE L. SWANSTROM

ACHALASIA

Achalasia is a primary motility disorder of the esophagus characterized by the absence of peristalsis and failure of swallow-induced relaxation of the lower esophageal sphincter (LES). It is a rare disorder with estimated incidence of 1 in 100,000 annually and prevalence of 10 in 100,000.¹ “Cardiospasm” was first described in the 1600s, with the first reported treatment being peroral passage of a whale rib-bone with an attached sponge.² The disease was renamed *achalasia* when Lendrum proposed the mechanism of failure of LES relaxation in 1937.³ Patients tend to present with progressive dysphagia to liquids then solids, as well as volume regurgitation. The traditional diagnosis is an esophagram, which demonstrates a tapering of the distal esophagus on esophagram with a “bird’s beak” appearance (Figure 25.1).

Subtypes

Achalasia has been recently classified into three manometric subtypes (Chicago classification) using high-resolution manometry (HRM): type 1 is associated with minimal esophageal contractility or pressurization, type 2 involves intermittent periods of esophageal compartmentalized contractions, and type 3 consists of secondary and tertiary spastic distal esophageal contractions⁴ (Figure 25.2).

These subtypes respond differently to various treatments. Type 2 responds better to pneumatic dilation (96% success rate) than type 1 (56%) and type 3 (29%).⁵ Similarly, success rates of laparoscopic myotomy vary by subtype: 92% for type 2, 85% for type 1, and 70% for type 3.⁶ However, the European Achalasia Trial demonstrated equivalent outcomes for dilation and myotomy for type 1, while type 2 patients had improved outcomes with dilation. In this study, type 3 patients had improved

outcomes with myotomy, although this was not statistically significant and was felt to be a type 2 error.⁷ Peroral endoscopic myotomy (POEM) has not been extensively analyzed by achalasia type, but there are reports of up to 100% clinical success rates for all classifications combined.^{8,9}

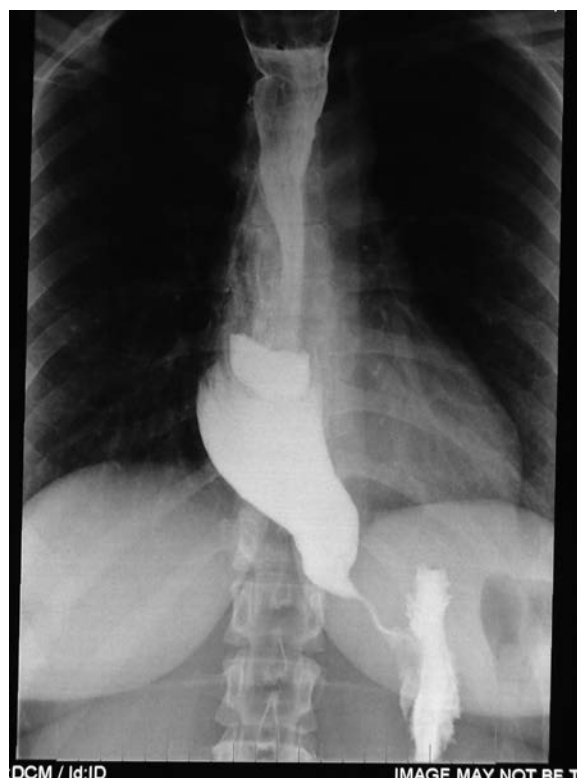


Figure 25.1 Barium esophagram showing typical features of achalasia, most particularly “bird beak appearance” of the distal esophagus.

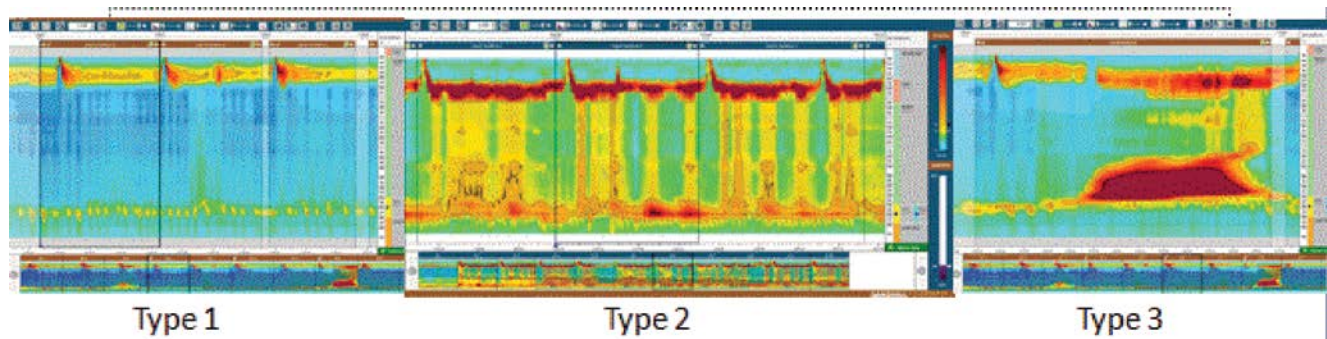


Figure 25.2 The Chicago classification divides achalasia into three types based on manometric criteria.

Contemporary evaluation

An esophagram remains a useful initial test, and timed barium swallow is an important tool for longitudinal follow-up. The definitive diagnosis is confirmed with manometry, preferably HRM. Esophagogastroduodenoscopy with biopsy is important to exclude cancer, and timed barium swallow completes the preoperative workup. Twenty-four-hour pH monitoring is not generally useful, even though “heartburn” is a common complaint in achalasia.

Treatment options

Surgical myotomy has long been a mainstay of achalasia treatment. It was initially proposed by Heller¹⁰ in 1913 as a thoracotomy and two separate 8 cm myotomies, 180° apart. The technique has been modified over the years and now generally involves a single anterior myotomy with partial fundoplication to decrease the risk of iatrogenic reflux. The laparoscopic¹¹ and thoracoscopic¹² approaches were described in 1991 and 1992, respectively. Modern alternatives to surgical treatments include endoscopic dilation, endoscopic botulinum toxin injection, and the recently described POEM.

PERORAL ENDOSCOPIC MYOTOMY

History

Ortega¹³ first described endoscopic myotomy in 1980 with division of the mucosa and muscle of the LES with two short full-thickness incisions. Despite satisfactory outcomes, the technique was not adopted due to concern for esophageal perforation. Twenty-four years later, Gostout¹⁴ described a mucosal flap technique for endoscopic mucosal resection, which was also recognized as safe transmural access for natural orifice transluminal endoscopic surgery (NOTES). This technique was adopted by Pasricha¹⁵ to perform a “submucosal endoscopic esophageal myotomy” in

a porcine model in 2007. Inoue presented the first human experience in 2008 with four patients and named the procedure “POEM.” He published a series of 17 patients 2 years later.¹⁶

Preoperative considerations

Today there are no absolute contraindications to POEM, and there are descriptions in the literature of POEM in pediatric and aged patients, for all variants of achalasia, for patients with previous interventions (Botox, balloon, POEM, or Heller), and end-stage “sigmoid” esophagus. The only absolute contraindication to the POEM procedure at this time is the inability to tolerate general anesthesia. The authors, however, consider a large hiatal hernia to be a relative contraindication to POEM due to a higher risk of symptomatic reflux and prefer laparoscopic myotomies with partial fundoplication and hernia repair in these patients.

The authors’ practice is to place patients on a clear liquid diet for 24 hours prior to the procedure and to treat prophylactically with 5 days of preoperative nystatin swish and swallow, as well as a single dose of first-generation cephalosporin within 30 minutes of mucosotomy. A single dose of steroids (dexamethasone 10 mg) is given just before surgery to minimize mucosal edema at the site of the mucosotomy, which facilitates closure. The procedure requires endotracheal intubation and general anesthesia, and most commonly occurs in the operating room to allow for close monitoring and potential intervention if complications occur.

Technique

There are five steps to the POEM procedure: endoscopic measurements, saline lift and mucosotomy, submucosal tunnel, circular myotomy, and mucosotomy closure. Reported operative times are 90–120 minutes.^{17–20} The learning curve has been estimated to be approximately 20

Table 25.1 Basic equipment needed for POEM

General setup	Mucosotomy
Video tower	Generator/ground pad (mucosotomy: 60 cut)
Endoscope	(tunnel: 60 spray tunnel, myotomy: 40 spray)
CO ₂ regulation unit	Active cord
Low-flow tubing	Injection needle
Flushing pump	Needle knife
Large pitcher—for lifting solution	Balloon
10 cc controlled syringes	
Wash towels—grip of endoscope	Tunnel
Alcohol swabs—camera cleaning	Dissecting caps—soft, hard, or angled
Toothbrushes—for cleaning needle knives	Hemostatic graspers
Wire bucket—temporary wire storage	Triangle tip knife
	Myotomy
Measurement	Triangle tip knife
Data sheet	L-hook
Overtube	
	Closure
Lifting solution	Clip—large and small
1 mL Indigo Carmine diluted in 500 mL NS	Suture—OverStitch, requires dual-channel scope
±epinephrine 1:1,000 1 mg/mL	

procedures,¹⁹ with 30 procedures suggested before attempting POEM after failed Heller myotomy.²¹ **Table 25.1** lists the basic equipment that should be available for the procedure.

STEP 1: ENDOSCOPIC MEASUREMENTS

We recommend placement of a short overtube at the beginning of the case unless the patient is having a long thoracic myotomy. The overtube provides added stability to the endoscope and may result in a smaller mucosotomy to close at the end of the procedure. Anatomic landmarks are measured in reference to the overtube. Submucosal tattooing, with methylene blue or India ink, of the endpoint of the myotomy can be helpful for identification from within the tunnel.

STEP 2: SALINE LIFT AND MUCOSOTOMY

The site for the mucosal incision should be 3–4 cm proximal to the determined start of the myotomy. We determine the proximal extent of the myotomy based on the HRM classification of the achalasia, intraoperative EndoFlip (Crosspon, Gallway, Ireland) measurements,²² and visual identification of the top of the high-pressure zone. In general, a shorter myotomy is made for type 1 and 2 achalasia and a longer esophageal myotomy for Chicago 3 achalasia. We prefer the anterior lesser curve position (“2 o’clock position”) for the myotomy, although posterior (6 o’clock) is possible as well. The saline lift is performed by injecting a dilute methylene blue saline solution, with or without epinephrine (“lifting solution”), into the submucosal space through a 23-gauge endoscopic injection needle. A 1.5 cm mucosotomy is then performed using a hook or triangle-tip (TT) cautery device with cutting current.

The endoscope, which is fitted with a vented, tapered, or angled dissection cap, is inserted through the mucosotomy and into the submucosal plane. Insertion can be aided with the use of a 15 mm biliary extraction balloon to elevate the edges of the mucosa.

STEP 3: SUBMUCOSAL TUNNEL

The esophageal mucosa and submucosa are separated from the underlying circular muscle fibers using spray cautery (**Figure 25.3**). Hydrostatic dissection is performed every

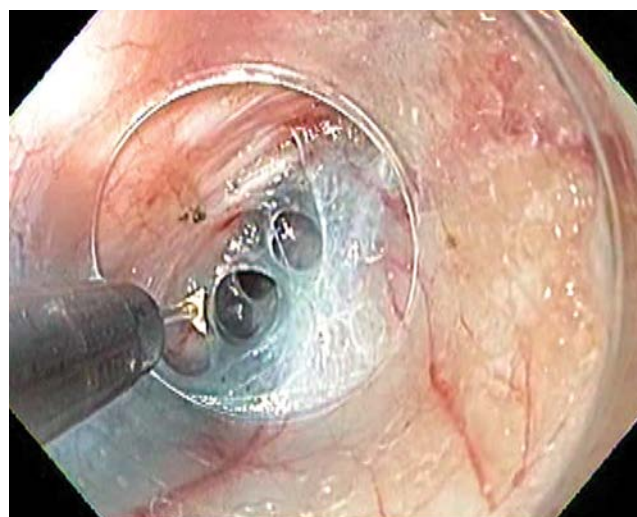


Figure 25.3 Typical endoscopic view of the submucosal plane.

few centimeters with lifting solution. Large bridging vessels are occasionally encountered and can be controlled with a coag grasper and soft cautery. Difficult bleeding can be controlled with direct pressure by advancing the dissecting cap and applying pressure. The distal extent of the dissection can be identified by encountering the tattoo-placed previous India ink or by visualizing the transition from orderly esophageal vessels to the submucosal palisades characteristic of the gastric plane. Alternatively, the endoscope can be withdrawn from the tunnel and advanced through the true lumen into the stomach, where a retroflexed view can confirm mucosal blanching caused by the tunnel extending across the gastroesophageal junction (GEJ). During creating of the submucosal tunnel, care must be taken to avoid mucosal injury from cautery or shear injury from bowing of the endoscope. Spiraling of the tunnel is prevented by maintaining the same operative position and by always making sure the circular fibers are parallel to the end of the cap.

STEP 4: CIRCULAR MYOTOMY

Before proceeding with myotomy, the anatomic measurements should be confirmed. The myotomy begins 2 cm distal to the most distal extent of the mucosotomy and proceeds antegrade to allow the dissecting cap to place tension on the muscle fibers. The myotomy consists of division of the circular muscle fibers using an Endocut current via a triangle tip or hook cautery. Once the circular fibers are divided, the longitudinal muscle fibers are easily visible (Figure 25.4). The longitudinal fibers are very thin, and splitting often occurs under the pressure of the dissecting cap, which will reveal mediastinal structures beyond the intact esophageal adventitia. Such “mediastinal exposure” is common and does not mean that a full-thickness perforation has happened, as there is a thin adventitia surrounding the longitudinal plane. The plane between the circular muscle fibers and the longitudinal fibers can then be followed distally with continued myotomy. The space often becomes tight at the GEJ, and a diaphragmatic impression is also expected. Forcing the dissecting cap through this area should be avoided, as it can cause endoscopic bowing and further mucosotomy tearing. Progressive lifting and dissection will always eventually permit passage of the endoscope into the gastric plane. The myotomy should be continued well onto the gastric wall as confirmed by the previously placed tattoo or confirmation by retroflexion. We also repeat the EndoFlip measurement to ensure an increase in the cross-sectional area and, more importantly, an improvement in the compliance of the LES (Figure 25.5).

STEP 5: MUCOSOTOMY CLOSURE

The endoscope is withdrawn into the true esophageal lumen, and dissection length is evaluated. If adequate dissection has occurred, the mucosotomy is then closed using endoscopic clips or endoscopic sutures. Any mucosal burns or perforations should first be clipped, and then the mucosotomy is closed from proximal to distal.

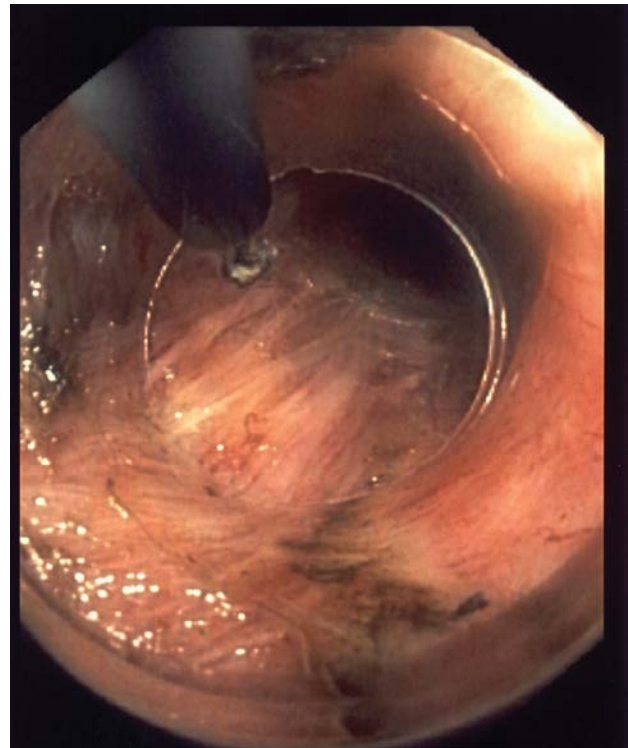


Figure 25.4 After division of the circular muscle layer, the longitudinal muscle fibers are visible.

Postprocedure care

Before initiating oral intake, the authors' standard practice is to obtain a water-soluble contrast esophagram on postoperative day 1, followed by 7 days of a pureed diet, and then a regular diet. The hospital length of stay is approximately

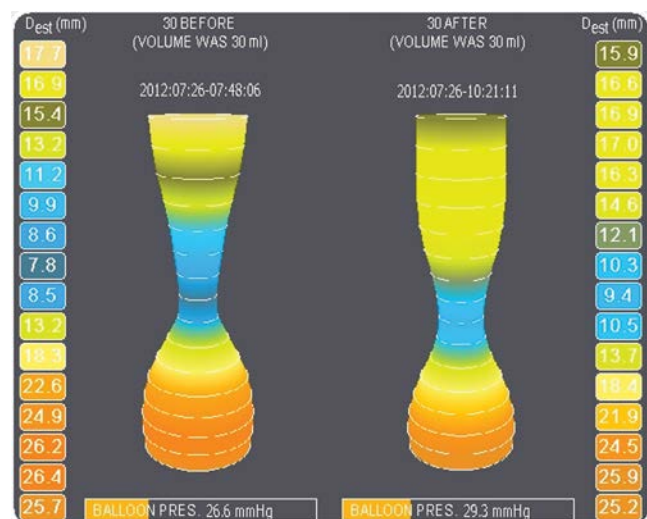


Figure 25.5 Pre- and post- impedance planimetry documents normalization of sphincter diameter and compliance.

1 day,¹⁸ and patients return to regular activity after 4 days, on average.²⁰

RESULTS

Eckardt Clinical Score is used to evaluate subjective post-POEM results. It is a validated tool that allows for symptom grading in severity and frequency of dysphagia, chest pain, regurgitation, and degree of weight loss.²³ Scores of three or less are used to define successful symptom relief. Eckardt scores range from 5.5–8.8 before POEM to 0–1.4 after POEM.^{8,9,17,20,24} Dysphagia relief after POEM has been demonstrated to be greater than 90% in short- and long-term follow-up, with complete dysphagia relief occurring more commonly for achalasia than nonachalasia patients.^{20,24–27}

Objective results can also be evaluated. Timed barium swallow can be used to measure improvements in esophageal emptying; it has been shown to correlate with subjective improvements in swallowing in POEM patients. HRM has also been used to demonstrate appropriate decreases in LES resting and residual pressures after POEM.^{8,17}

POEM COMPARED TO HELLER MYOTOMY

POEM has compared favorably to laparoscopic Heller myotomy with fundoplication. Two studies have demonstrated POEM to in fact have improved outcomes. These included shorter operative times, lower blood loss, shorter hospital stay, better short-term Eckardt scores, similar intermediate Eckardt scores, similar reflux, and lower dysphagia rates.^{17,18} Randomized controlled trials are underway to further compare the two procedures.

Newer indications for POEM

POEM AFTER PRIOR TREATMENTS

POEM has been shown to be both safe and effective after prior endoscopic intervention. Due to concerns for submucosal fibrosis from dilations or injections, these procedures were felt to be contraindications to POEM initially. As experience increased, POEM has been successfully completed with no increases in procedure length or perioperative complication rates after prior intervention.²⁸ POEM has also been reported after prior laparoscopic myotomy; it is technically difficult, but safe and effective with published efficacy of 91.7%–100%.^{20,29,30} In the setting of failed Heller myotomy, some recommend creation of the submucosal tunnel in the posterior aspect of the esophagus²⁵ or the lateral wall.⁹

NONACHALASIA MOTILITY DISORDERS AND END-STAGE ACHALASIA

In addition to achalasia, POEM has been used for other primary motility disorders. Compared to achalasia, patients with diffuse esophageal spasm tend to demonstrate a

slower and less consistent resolution of their symptoms after POEM.^{19,31} POEM for nutcracker esophagus^{20,32} and jackhammer esophagus³³ have also been described with successful results. Extended proximal myotomies should be considered for noncardiac chest pain as well as type 3 achalasia, which can be extended from a few centimeters from the cricopharyngeus to the gastric cardia.

End-stage achalasia or “sigmoid” esophagus is typically more difficult technically to treat and has poorer clinical results. As with dilation or Heller myotomy, many end-stage patients will have continued functional deterioration, and up to 5% will require esophagectomy.³⁴ End-stage achalasia was felt to be a contraindication for POEM in the past, but successful therapy has been described in small subsets of larger studies,^{16,20} as well as one recent study of 32 patients with long-term follow-up and a 96% success rate.³⁵

Complications

Inadvertent mucosal injuries, burns, and small perforations can occur in up to 25% of POEM cases, but these are clinically irrelevant and can almost always be treated with endoscopic clips, sutures, stents, Endoloops, or fibrin sealant. Full-thickness perforations are rare but can cause serious harm to patients if not recognized and repaired at the time of the procedure. Mucosotomy dehiscence and postoperative bleeding are also rare and can almost always be controlled endoscopically.^{20,36}

Pneumoperitoneum, pneumomediastinum, and pneumothorax are common occurrences during the procedure and are not felt to be complications. As long as carbon dioxide is used for the procedure, these rarely require intervention due to reabsorption. If necessary due to symptoms, sterile needle decompression, without indwelling drain placement, can be performed in the peritoneal cavity or the anterior chest during or after the procedure.^{20,36}

GASTROESOPHAGEAL REFLUX DISEASE

Gastroesophageal reflux disease (GERD) is a well-established side effect of Heller myotomy, and partial fundoplications are performed to reduce the rate of GERD after myotomy.³⁷ Although POEM does not allow for a fundoplication at the time of myotomy, the intact phrenoesophageal ligaments and preservation of the longitudinal esophageal muscle fibers are believed to reduce the incidence of GERD after POEM. Approximately 10%–40% of patients will demonstrate abnormal reflux after POEM,^{18,20,38} which compares favorably to rates of 20%–40% after Heller myotomy with fundoplication.^{37,39,40} Up to 50% of patients with post-POEM reflux can be asymptomatic,²⁰ and up to 44% of patients with symptoms of reflux have normal acid exposure⁸; the authors recommend postoperative pH testing in all patients to identify those with increased acid exposure after POEM, and consideration of antacid medication or selective fundoplication in this subset.

CONCLUSION

POEM is a safe and very effective treatment for achalasia and other motility disorders of the esophagus. It compares favorably to laparoscopic Heller myotomy, with some improved outcomes and similar reflux rates in nonrandomized studies. In the short time since its introduction in 2008, it has been utilized worldwide and has gained worldwide acceptance. It may become the preferred primary treatment for esophageal motility disorders if studies continue to yield consistent excellent results.

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Transvaginal cholecystectomy

BILL RAN LUO AND ERIC S. HUNGNESS

INTRODUCTION

Laparoscopic cholecystectomy is one of the most common operations performed in the world today. Standard of care for cholecystectomy prior to the 1980s was via an open incision, but with acceptance of laparoscopic cholecystectomy in the 1990s, the world of minimally invasive surgery for gallbladder pathology has bloomed.¹ Given the push for surgeons to innovate and develop less invasive surgical techniques, natural orifice transluminal endoscopic surgery (NOTES) cholecystectomies are now prevalent.² In this chapter, we review the operative techniques used at our institution for transvaginal cholecystectomy.³⁻⁵

PATIENT SELECTION, TESTING, AND CONTRAINDICATIONS

Transvaginal cholecystectomies (TVCs) should be performed in the setting of benign diseases of the gallbladder, including small polyps or symptomatic cholelithiasis. Acute cholecystitis and choledocholithiasis are relative contraindications given the potential for difficult dissection, along with any situation with a high likelihood of gallbladder-related malignancy. A preoperative right upper quadrant ultrasound should be obtained, as gallstones larger than 2–3 cm may cause inadvertent extension of the colpotomy, and can be considered a relative contraindication. Other contraindications include prior abdominal/pelvic surgery, history of vaginal trauma, severe endometriosis, enlarged uterus or presence of large fibroids, dyspareunia, abnormal Pap smear, and any malignancy involving the cervix or vagina.

Routine preoperative evaluation that would otherwise be performed for patients undergoing standard multiport laparoscopic cholecystectomy (MPLC) should be done for all TVC patients. In addition, a normal pelvic examination

by a gynecologist and a negative Pap smear within the prior 12 months to rule out malignancies is required.

PATIENT POSITIONING AND OPERATIVE PREPARATION

Patients are placed in a low lithotomy position with hips flat in neutral position. This minimizes any interference between the patient's left thigh and the laparoscopic instruments. The right arm should be tucked and left arm can be extended. A urinary catheter should be placed and the vagina prepared with povidone-iodine solution. The surgical team should take care to place the patient in proper lithotomy position, in order to prevent compressive nerve injuries. The operating surgeon begins the procedure seated between the patient's legs with the endoscopy assistant standing to the left of the surgeon. The laparoscopic assistant should be positioned on the patient's left with the scrub technician to his or her left. The endoscopy tower and monitor should be placed to the patient's right just cephalad to the right lower extremity, and the laparoscopy monitor on the patient's left, above the left upper extremity.

INITIAL ABDOMINAL ACCESS

A hybrid approach is currently recommended for all TVCs. The abdominal cavity is accessed at the umbilicus with a Veress needle, and a 5 mm port is placed, setting the insufflation pressure limit to 12 mm Hg.

COLPOTOMY

Early on in the learning curve for the procedure a board-certified gynecologist experienced in vaginal gynecologic



Figure 26.1 Bladed trocar insertion technique.

surgery should be present to obtain transvaginal access. After developing comfort after several procedures, the abdominal surgery team should be capable of performing the colpotomy access. A speculum is placed into the vagina and a uterine manipulator is placed in order to antevert the uterus. The vaginal mucosa is elevated posterior to the cervix and scored carefully. Under direct laparoscopic visualization, an incision is made through the cul-de-sac just anterior to the rectum but posterior to the cervix. The colpotomy should be large enough to accommodate a 15 mm trocar. Then 0-Vicryl anchoring sutures are placed at each side of the incision, leaving the needles attached for closure at the conclusion of the procedure. Alternatively, a laparoscopic bladed trocar can be directly inserted into the pouch of Douglas between the uterosacral ligaments (**Figure 26.1**). At this point, there are two different techniques for performing the dissection. The first utilizes a gastroscope without any additional transvaginal instruments. The second technique utilizes the Endoeye (Olympus) deflectable endoscope and places a separate 5 mm trocar alongside the endoscope for a flexible grasper (**Figure 26.2a and b**). At our institution, we have switched to the latter, as it mirrors the dissection for MPLC more closely and was found to dramatically improve operative times.

SURGICAL DISSECTION

The umbilical 5 mm port is used to accommodate the Endograb (virtual ports) device used for initial gallbladder retraction. One end of this device grasps the gallbladder tissue, and the other end, which is connected by a nitinol wire, anchors onto the peritoneum thus retracting the gallbladder (**Figure 26.3**). This replaces the traditional fundus retractor and allows the transvaginal flexible grasper to be used for lateral retraction on the infundibulum.

The standard dissection should be similar to that of an MPLC. Varying amounts of dissection through the 5 mm

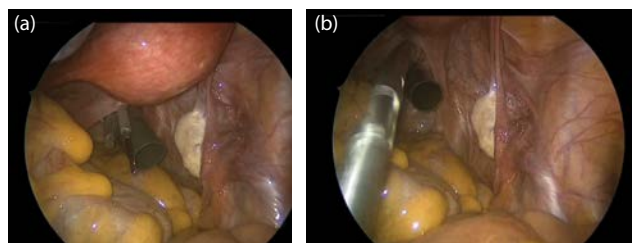


Figure 26.2 Additional introducer sheath inserted along the initial port (a) with subsequent insertion of flexible retractor (b).

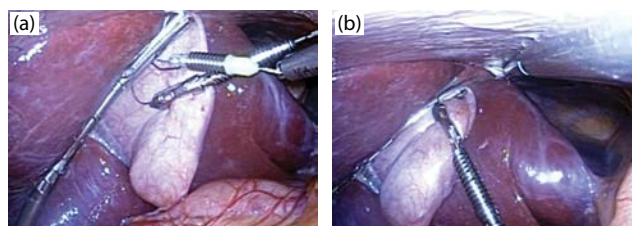


Figure 26.3 Endograb (virtual ports) device used for initial gallbladder retraction. Initial deployment on gallbladder infundibulum (a) and grasping of peritoneum with the opposite end (b).

laparoscopic port can be performed. Omental attachments can either be taken down bluntly or with cautery. Medial and lateral peritoneal attachments are freed off the gallbladder with any commercially available hot snare cautery or biopsy graspers. Careful hemostasis should be achieved, as there is usually only one laparoscopic port available with which to obtain hemostasis. Once the critical view of safety is obtained, the cystic duct and artery can be clipped through the laparoscopic port with a 5 mm clip applicator. The gallbladder is then carefully removed off the liver using the tip of a snare cautery device.

SPECIMEN EXTRACTION

The laparoscope is reinserted through the umbilical 5 mm port and the specimen is retrieved transvaginally through the larger trocar. Great care should be taken with known gallstones greater than 3 cm, as there is an increased risk of extending the colpotomy.

CLOSURE

Using the initially placed 0-Vicryl stay sutures, the edges of the vaginal incision are visualized and inspected for any lateral extension. The colpotomy is then closed with the 0-Vicryl sutures in a running fashion, utilizing long needle

drivers. Insufflation is released through the 5 mm umbilical port site, and the skin is closed with a dissolvable 4-0 suture.

INTRAOPERATIVE TROUBLESHOOTING

As experience with TVCs increase, comfort with addressing complications through the normal access sites will improve. However, patient safety should not be compromised, and if intraoperative complications are not able to be expeditiously resolved, additional laparoscopic ports should be placed. Conversion to conventional laparoscopy or laparotomy should also be considered.

Bleeding can occur during access or dissection. It is easiest to control the bleeding with the umbilical port using either a 5 mm clip applicator or forceps with electrocautery under endoscopic visualization. Endoscopic control is much more difficult given the lack of appropriate instruments currently.

Bowel and bladder injury have been described for TVCs. Direct laparoscopic visualization during the initial colpotomy and for all transvaginal instrument exchanges is recommended. The use of a uterine manipulator also reduces these risks. Injuries identified intraoperatively are handled in standard fashion after conversion to a standard laparoscopic or open technique. Delayed presentation of the injury is possible; therefore, a high index of suspicion should be maintained if the postoperative course is abnormal.

Suspicion for biliary tree injury should be investigated with intraoperative cholangiography. Insertion of other abdominal ports or conversion to conventional laparoscopic or open cholecystectomy should be performed when required for full evaluation of potential biliary injuries.

POSTOPERATIVE CARE

Umbilical port site pain after a TVC is usually minimal and should be adequately controlled with acetaminophen or a mild narcotic. Most patients do not complain of any perineal or vaginal discomfort after TVC. Some patients may experience mild spotting. Patients should be counseled that nothing should be inserted into the vagina for at least 4 weeks after the procedure to allow healing of the vaginal incision. Patients should be instructed to call with any heavy vaginal bleeding (more than 1 pad per hour) or foul-smelling vaginal discharge, as these symptoms could signify an infection of the colpotomy site. Diet advancement and bowel regimens should parallel that of a conventional laparoscopic cholecystectomy.

OUTCOMES

TVC is one of the leading access areas for NOTES cholecystectomies, mainly due to the long-term safety data from gynecologic surgery. However, the safety of all new techniques requires monitoring, making the development of

an international European NOTES surgery registry necessary. The creation of a German database also delivered an independent evaluator for safety and monitoring of NOTES outcomes. Data published from these two registries demonstrated comparable complications rates, pain scores, and recovery times to MPLC.

The International Multicenter Trial on NOTES (IMTN) and the German Registry D-NOTES demonstrated complication rates of 6.9% and 3.1%, respectively.⁶⁻⁸ The most common complications requiring surgical intervention were intraoperative bleeding, intraoperative bowel injury, and cystic duct stump leak. There were no reported cases of skin or soft tissue infections from these registries, likely secondary to the transvaginal extraction technique. From both registries only two instances of postoperative intra-abdominal infections were reported out of over 1,000 patients (0.77%). This dispels the initial worries regarding the sterility of transvaginal access for TVC. The incidence of rectal injury secondary to TVCs also appears low, with only two reported incidences from the registries. Safety was improved with consistent hybrid access using the initial abdominal port for direct visualization.

Results in the United States have been comparable to that of European Centers.⁹⁻¹¹ However, as there is no established registry in the United States, the case reports are small, ranging from 7 to 61 patients. Studying learning curves by judging operative times when introducing TVCs to fellowship-trained surgeons estimates about 15 cases to be necessary to become proficient.¹¹ All of the above results demonstrate that with care TVC is a safe alternative to MPLC and delivers comparable outcomes.

ACKNOWLEDGMENTS

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Transvaginal appendectomy

KURT ERIC ROBERTS AND STEPHANIE G. WOOD

INTRODUCTION

The modern era of surgery has brought many new techniques and instrumentation. Laparoscopic and endoscopic approaches to classically open surgery have established new technical challenges to the skill set of surgeons. Since the first description of laparoscopic appendectomy in 1983 by Semm,¹ the quest to minimize abdominal wall trauma has been a priority that led to the extension of natural orifice transluminal endoscopic surgery (NOTES). The anticipated benefits are a reduction in postoperative pain, shorter convalescence, avoidance of wound infections, and abdominal wall hernias, as well as the absence of visible scars on the abdomen. The use of transvaginal NOTES surgery has been shown to be a safe and effective approach to cholecystectomy and incidental appendectomy (during hysterectomy). However, the use of transvaginal NOTES for acute general surgery pathology such as appendicitis remains controversial. This chapter discusses the evolution of transvaginal appendectomy, surgical approaches such as pure and hybrid (endoscopic or laparoscopic), as well as the current literature.

HISTORY OF TRANSVAGINAL APPENDECTOMY

The first reports of transvaginal appendectomy were published in the context of gynecological procedures such as an incidental appendectomy performed during a transvaginal hysterectomy in 1949.² Palanivelu et al. was recognized as the first to publish a transvaginal appendectomy for appendicitis in 2008.³ Yet, Tsin et al. had already published a transvaginal appendectomy on three patients in the gynecological literature in 2001 prior to the advent of NOTES.⁴

Bernhardt et al. also reported a pure transvaginal appendectomy using endoscopic instruments shortly thereafter.⁵

In 2009, Horgan et al. described one transvaginal hybrid NOTES appendectomy in a case series of transgastric and transvaginal NOTES.⁶ Tabutsadze and Kipshidze reported two transvaginal appendectomies using a single-channel gastroscope.⁷ Nezhat et al. described 42 patients who underwent incidental appendectomy at the time of total laparoscopic or laparoscopic-assisted hysterectomies, whereby the appendix was transected with a stapler and removed transvaginally.⁸

Since the early reports of transvaginal appendectomies, the two main established approaches include pure or hybrid transvaginal appendectomy utilizing endoscopic, laparoscopic instruments, or both.

INDICATIONS AND CONTRAINDICATIONS

Preoperative considerations to proceed with transvaginal access surgery are varied. Most studies limit inclusion criteria to age 18–65 with a score of I–II in the American Society of Anesthesiologists classification system.^{9–12} Complicated appendicitis is usually an exclusion criterion.^{9–11,13} Morbid obesity (body mass index >35 kg/m²) is also a frequent exclusion measure. While previous pelvic surgery is not always an exclusion criterion, it is advisable during pure transvaginal surgery. Other contraindications reported include ongoing pregnancy until 8–12 weeks' postpartum, genital infection, endometriosis, neoplasms of the vulva, vagina, and an intact hymen.¹⁴ Patients should undergo a gynecological examination prior to surgery.

POSITIONING

After general anesthesia, the patient is placed in the low lithotomy (Lloyd-Davies) position in Allen stirrups. The arms are tucked to the patient's sides. The vagina is

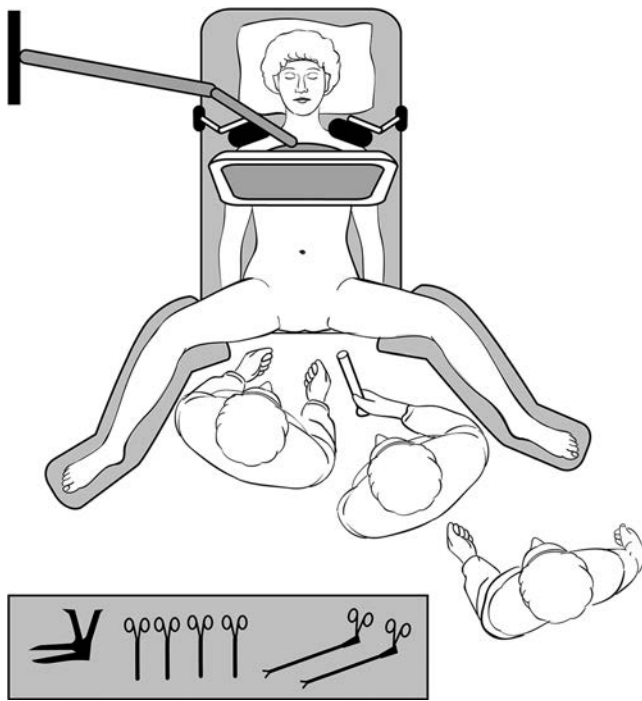


Figure 27.1 Operative positioning for a pure transvaginal appendectomy.

disinfected with a topical antiseptic solution, usually povidone-iodine, and a urinary catheter is placed. The abdomen is also prepped and draped. Antibiotic prophylaxis is typically given. The operating surgeon is positioned between the patient's legs, and when hybrid laparoscopic procedures are performed, a first assistant is on the patient's left-hand side (**Figure 27.1**).

OPERATIVE APPROACHES

The pure transvaginal appendectomies described in the literature include both flexible endoscopic and rigid laparoscopic approaches.

PURE TRANSVAGINAL APPENDECTOMY

Access to the peritoneal cavity during pure transvaginal appendectomy is obtained by incising the mucosa of the posterior fornix of the vagina through to the peritoneum in the pouch of Douglas or cul-de-sac, with or without the assistance of a gynecologist. A weighted speculum is introduced to the vagina and a uterine retractor is used to lift the uterus anteriorly to expose the posterior vaginal fornix. The cervix is grasped with a single-toothed tenaculum and retracted anteriorly. The colpotomy is created transversely in the posterior fornix using electrocautery or, alternatively, using scissors. Specific landmarks have been described to identify the "Triangle of Safety" within

the posterior fornix,¹⁵ using the base of the cervix and the rectovaginal fold.

Pure flexible endoscopic approach

A single-channel endoscope (gastroscope or colonoscope) is introduced after the colpotomy is made. Carbon dioxide insufflation can be established by the endoscope, or alternatively, a Veress needle inserted through the umbilicus can be used for insufflation. Endoscopic instruments introduced through the working endoscope channels are used to dissect the appendix. The endoscopic needle knife cautery is utilized for dissection of the mesoappendix. An Endoloop, introduced through the channel, is used for ligation of the base of the appendix. A second loop is placed slightly distal to the first, and the appendix is sharply transected between the Endoloops with endoscopic scissors. Grasping the free end of the Endoloop with an endoscopic grasper retrieves the appendix from the abdominal cavity.^{5,7}

Pure rigid laparoscopic approach

The pure rigid laparoscopic appendectomy technique employs the use of a SILS™ Port (Covidien, North Haven, Connecticut) that is inserted into the colpotomy site.¹¹ The SILS Port facilitates two 5 mm trocars and a 12 mm trocar. A 5 mm 30° laparoscope and two laparoscopic instruments, including a flexible reticulating endograsper for upward retraction of the appendix and a Maryland dissector to dissect the mesoappendix, are utilized. The mesoappendix is divided with a stapler or bipolar ligation device, and the appendix is divided with a laparoscopic GIA stapler. The appendix is then retrieved with a standard laparoscopic specimen bag and passed through the 12 mm port (**Figure 27.2**).

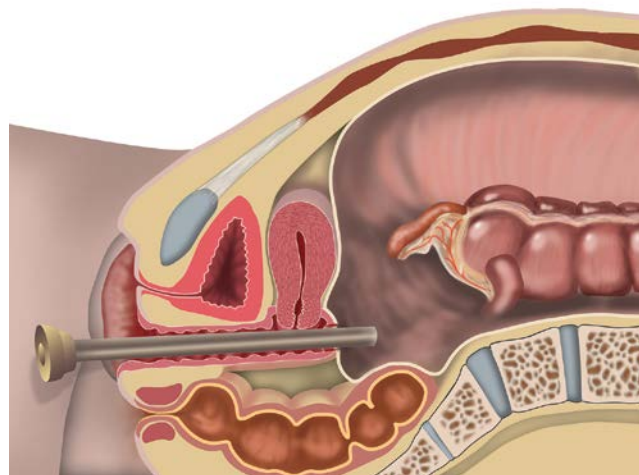


Figure 27.2 Pure transvaginal appendectomy. Sagittal view of a rigid laparoscopic transvaginal approach.

HYBRID TRANSVAGINAL APPENDECTOMY

In hybrid transvaginal appendectomy, access to the peritoneal cavity is obtained transumbilically with a Veress needle. Pneumoperitoneum is established to a pressure of 15 mm Hg, and a 5 mm trocar is placed through the umbilical incision. The patient is placed in steep Trendelenburg, and the pelvis is examined for adhesions that obliterate the pouch of Douglas. In absence of these findings, a colpotomy is performed under direct laparoscopic visualization by penetrating or incising the posterior fornix of the vagina with a trocar or scissors (or electrocautery), respectively ([Figure 27.3](#)).

HYBRID FLEXIBLE ENDOSCOPIC APPROACH

The working ports of the transvaginal endoscope are used to proceed with appendiceal dissection similarly to the pure endoscopic approach as previously described. The umbilical port acts as an added working port for a grasper to retract the appendix. Endoscopic coagulation forceps are used to

dissect the mesoappendix, and the appendiceal artery is coagulated.^{12,16} Alternatively, the endoscopic graspers are used to retract or lift the tip of the appendix, and the mesoappendix is dissected free using an ultrasonic scalpel introduced through the umbilical port.¹⁷ Endoscopic graspers retract the appendix, and a laparoscopic snaring device is introduced via the umbilical port to ligate the base of the appendix. Transection of the appendix is made with laparoscopic scissors or ultrasonic scalpel. The specimen is recovered transvaginally.

The addition of a transvaginal 12 mm trocar, parallel to the endoscope, can allow the use of a laparoscopic GIA stapler when encountering difficulty with ligating the base of the appendix.¹⁶ Jacobsen et al.¹³ described placing a dual-lumen 15 mm trocar through the colpotomy to accommodate both the endoscope and additional operating instruments. The appendix was retracted using a percutaneous Endoloop, and the mesoappendix was ligated with ultrasonic scalpel placed through the umbilical port. The appendix base is transected with a transvaginally placed articulating laparoscopic linear stapler, and the appendix is retrieved with an endoscopic retrieval bag.

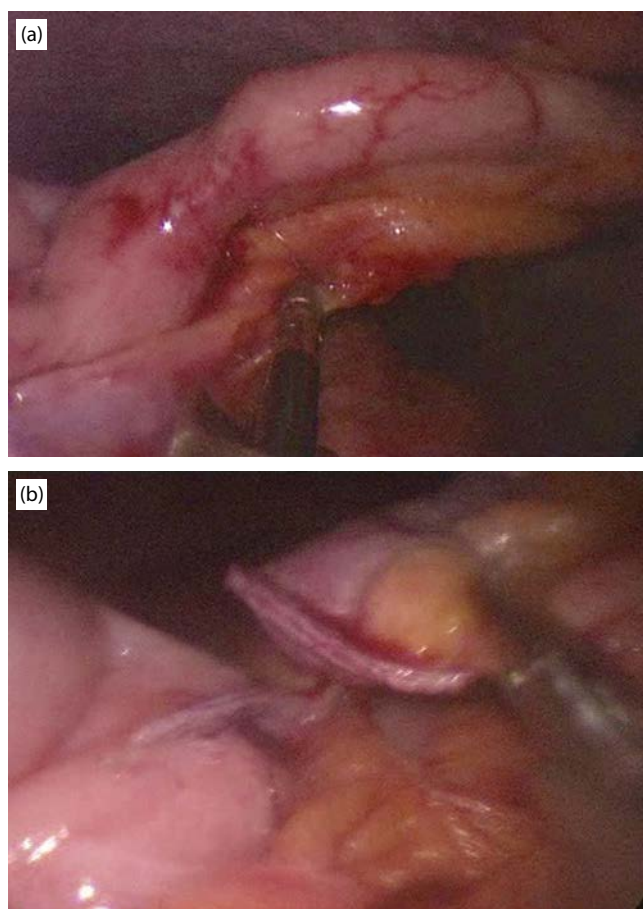


Figure 27.3 Pure transvaginal appendectomy using rigid laparoscopic instruments. (a) Dissection of mesoappendix with laparoscopic bipolar ligation device. (b) Appendix transection with laparoscopic stapler.

HYBRID RIGID LAPAROSCOPIC APPROACH

Knuth et al.¹⁴ placed a transvaginal 5 mm trocar followed by an adjacent 13 mm trocar for camera and stapler. Standard rigid laparoscopic instruments were used. The laparoscope was capable of alternating between the transvaginal or transumbilical port as needed for optimal visualization. A transvaginal rigid curved grasper forceps was introduced to retract the appendix. The mesoappendix could be divided with a stapler, coagulation, clips, or a combination. The specimen was retrieved transvaginally through the 13 mm port.

CLOSURE

At the completion of the transvaginal appendectomy for both pure and hybrid approaches, the pneumoperitoneum is released, and primary closure of the colpotomy is performed with a running braided absorbable suture under direct visualization. Postoperatively, most surgeons recommend 2–4 weeks pelvic rest before resuming intercourse. Some surgeons perform a routine gynecological pelvic exam at 2–4 weeks postoperatively ([Figure 27.4](#)).

OUTCOMES

Our own published experience compares pure rigid transvaginal appendectomy as described to conventional laparoscopic appendectomy.¹¹ The transvaginal appendectomy mean operating room time was 44 minutes. Length of stay and operative times between conventional laparoscopic and transvaginal appendectomy patients were similar. There



Figure 27.4 Closure of transvaginal incision with running absorbable suture.

were two complications in the transvaginal appendectomy group (intra-abdominal abscess and urinary retention) and two complications in the laparoscopic group (bowel obstruction and urinary retention). The transvaginal appendectomy patients reported a faster recovery compared to the laparoscopic patients. Of note, there was a decreased need for postoperative analgesia and faster return to work or normal activity for the transvaginal appendectomy patients.

Bernhardt et al.¹⁶ compared 10 laparoscopic appendectomy patients to 10 hybrid transvaginal endoscopic appendectomy patients. The median operating time in the transvaginal group was 75 minutes compared to 40 minutes for the laparoscopy group. One postoperative abscess was identified in the laparoscopy group for perforated appendicitis, and one transvaginal patient complained of postoperative abdominal pain with a negative diagnostic laparoscopy. A shorter hospital stay was noted for the transvaginal compared to laparoscopic patients. The transvaginal patient group reported a more rapid postoperative recovery to normal activities, health, and wellness compared to the laparoscopic group.

Knuth et al.¹⁴ described 13 hybrid rigid transvaginal appendectomies with no conversions to standard laparoscopy and a mean operative time of 52 minutes. Three postoperative complications (infected hematoma, abscess, and vaginal fungal infection) were reported.

TRANSVAGINAL VERSUS CONVENTIONAL LAPAROSCOPIC APPENDECTOMY

In the few studies comparing transvaginal appendectomy to laparoscopic appendectomy to date, the operative time was

shown to be significantly greater for transvaginal appendectomy compared to laparoscopic appendectomy.^{11,18} Postoperatively, transvaginal appendectomy patients were shown to have shorter length of hospital stay, less opioid requirement, and faster recovery to normal activities. Albrecht et al.¹⁸ noted higher cosmetic satisfaction in the transvaginal group compared to the laparoscopic group. Two studies assessing female sexual function noted that the female sexual function scores were unaffected by the transvaginal approach.^{16,19}

LAPAROSCOPIC VERSUS ENDOSCOPIC TRANSVAGINAL APPENDECTOMY

There are no studies directly comparing endoscopic to laparoscopic transvaginal appendectomy. However, the employment of standard laparoscopic instruments for transvaginal appendectomy may shorten the overall operative time compared to endoscopic instruments.^{11,14} The lack of a standard endoscopic platform creates a barrier to application for intra-abdominal surgery. Both techniques appear to have similar complication rates. Previous studies have suggested that endoscopic hemostatic devices are less effective than laparoscopic devices.²⁰ However, this has not been demonstrated in the transvaginal appendectomy literature to date. Difficulty with sterilization of endoscopes has been described,²¹ but there is a paucity of data in the current NOTES literature to address this issue adequately.

HYBRID VERSUS PURE TRANSVAGINAL APPROACH

The hybrid transvaginal appendectomy is a more common approach. This is likely due to visualization of safe entry of the transvaginal port and adds a working port optimizing triangulation of the appendix.²² This approach may be technically easier and may shorten the learning curve. However, there are no studies comparing outcomes of pure to hybrid transvaginal appendectomy to date.

SUMMARY

In the setting of uncomplicated appendicitis, transvaginal appendectomy has been shown to be safe and efficacious. No specific transvaginal approach, pure or hybrid, using endoscopic or laparoscopic instruments, has been shown to be superior. Yet, the hybrid approach may be technically easier and therefore safer compared to the pure transvaginal approach for most surgeons. Several studies of transvaginal appendectomy suggest that there is a faster recovery to normal activities and improved cosmetic results compared to conventional laparoscopic appendectomy. The role for transvaginal appendectomy in the overall management of acute appendicitis is a viable option for patients.

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Natural orifice surgery: Colectomy

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INTRODUCTION

Natural orifice transluminal endoscopic surgery (NOTES) represents the latest evolution in minimally invasive colorectal surgery. NOTES holds the promise of further minimizing surgical trauma and reducing surgical morbidity relative to laparoscopic surgery with the theoretical benefits of reduced incisional pain; wound-related complications, such as surgical site infection, hernia, and adhesive small bowel obstruction; shorter hospital stay; and faster return to work. Over the past several years, NOTES techniques have been applied to perform colorectal procedures of increasing complexity using both transvaginal and transanal approaches. NOTES transvaginal colorectal procedures evolved from the early NOTES transvaginal cholecystectomy and appendectomy experience, while transanal NOTES colorectal procedures were built on previous experience with transanal colonic pull-through for Hirschsprung disease and transanal proctosigmoidectomy for rectal prolapse. Based on the location of colorectal pathologies in direct line of reach to the anal orifice, these operations naturally evolved to use a transanal approach as the focal point for specimen extraction, eliminating the need for abdominal extraction sites. Transanal NOTES, in particular, was enabled by the introduction of specialized transanal endoscopic platforms that have facilitated transanal access and intra- and transluminal maneuvering and manipulations. Overall, NOTES colectomy has quickly transformed from a niche surgical technique dreamed up in the laboratory using pig and cadaver models to a number of NOTES procedures that, along with recent improvement in instrumentation and ongoing efforts toward standardization of surgical techniques and training pathways, have become increasingly adopted. Pioneers in the field of NOTES continue to carefully track and share their experiences to improve our understanding of how different routes of entry and specimen extraction may impact

intraoperative, postoperative, and long-term oncologic outcomes.

TRANSVAGINAL COLECTOMY EXPERIENCE

Transvaginal specimen extraction during colectomy was first described in 1996, and several published case reports and institutional case series have since refined this approach. Specimen extraction using the transgastric, transvaginal, or transanal route has generally been referred to as natural orifice specimen extraction (NOSE). When combined with laparoscopic right and left colon resection, NOSE aims to eliminate the need for the abdominal extraction site and thereby minimize incisional and other wound-related complications ([Table 28.1](#)).

With respect to indications for transvaginal NOSE, this approach best complements left-sided colonic resections based on the fact that the vagina is located immediately adjacent to and in line with the rectum. Assuming that adequate mobilization of the colon has been achieved and tension upon pulling of the specimen has been eliminated, resected colorectal specimens can be extracted and transected transvaginally without trauma to the bowel and its mesentery, followed by colorectal anastomosis. Transvaginal access to the peritoneal cavity is first obtained by making a small incision in the posterior vaginal vault, followed by insertion of a 12 mm trocar under laparoscopic visualization. Additional abdominal trocars are placed to perform standard laparoscopic mobilization of the left colon and/or sigmoid mobilization and transection of the inferior mesenteric vessels. Anal dilators can be inserted through the rectum to provide traction at the rectosigmoid junction, and following standard laparoscopic mobilization of the specimen, the rectum can be transected with a stapler inserted through the transvaginal trocar. The colon is subsequently pulled and divided transvaginally through a

Table 28.1 Transvaginal NOTES colectomy series

Series	Year	n	Type of operation	Pathology	Number of ports	Operative time (minutes)	Morbidity (n)	Length of stay (days)
Abrao ⁵¹	2005	8	Sigmoid resection	Endometriosis	4	177.5 (119–251)	None	4.13 (2–5)
Breitenstein ⁵²	2006	2	Sigmoid resection (+hysterectomy)	Diverticulitis	4	NS	<i>Clostridium difficile</i> colitis (1), urinary tract infection (1)	15 and 9
Boni ⁵³	2007	11	Sigmoid resection	Endometriosis	4	240 (63)	None	5 (2)
Wilson ⁵⁴	2007	1	Right hemicolectomy	Carcinoma	4	NS	None	NS
Ghezzi ⁵⁵	2008	33	Sigmoid resection	Endometriosis	4	290 (200–390)	Seroma (1), retention (3)	6.7 (1.8)
Palanivelu ⁵⁶	2008	7	Restorative proctocolectomy	Familial adenomatous polyposis	5	222.5 (165–280)	Leakage (1)	25.5 (11–40)
Burghardt ⁵⁷	2008	1	Right hemicolectomy	Adenoma	3	192	Lower gastrointestinal bleeding	NS
Pickron ⁵⁸	2009	1	Ileocecal resection	Endometriosis	4	NS	None	NS
McKenzie ⁵⁹	2010	4	Right hemicolectomy	Benign and malignant	4	212.3	Internal hernia (1)	3, 4, 5, 34
Awad ³	2011	14	Right hemicolectomy	Benign and malignant	5	229 (172–360)	Bleeding (1), ileus (3)	9.6 (2–30)
Park ⁵	2011	34	Right hemicolectomy	Malignant	5	170.8 (46.4)	Ileus (1), retention (1), bleeding (2)	7.9 (0.8)
Tarantino ⁶⁰	2011	34	Sigmoid resection	Diverticulitis	4	172.5 (107–312)	Leakage (1)	6 (3–23)
Stipa ⁶¹	2011	1	Right hemicolectomy	Carcinoma	NS	265	None	7
Karahasanoglu ⁶²	2011	1	Right hemicolectomy	Crohn disease	2	140	None	4
Torres ⁶³	2012	21	Sigmoid and high anterior resection	Benign and malignant	4	None	None	3–6
Franklin ¹	2013	26	Right hemicolectomy	Benign and malignant	4	159 (27.1)	None	5.5 (2.5)
Nishimura ⁶⁴	2013	5	Anterior resection	Malignant	NS	235.4	Chyloperitoneum (1)	6.6
Bulian ⁴	2014	122	Sigmoid resection, left colectomy, ileocecal resection, right colectomy, proctocolectomy	Benign and malignant	3 (1–5)	131 (55–752)	12.20%	8 (2–28)
Lamm ⁶⁵	2015	37	Sigmoid resection	Diverticular disease	NS	149 (108–187)	10% complication rate (sepsis [2])	6 (5–8)

Note: NS, not stated.

wound protector, followed by subsequent placement of the anvil in the lumen of the proximal colon with end-to-end stapled colorectal anastomosis. At the end of transvaginal procedures, the posterior colpotomy is closed using absorbable sutures. **Figure 28.1** depicts operative images from a transvaginal colectomy.

Despite initial concerns with potentially seeding tumor cells during transvaginal NOTES colorectal procedures, resections have been successfully performed for both benign and malignant colorectal diseases without deleterious oncologic outcomes.¹ The use of a transvaginal sleeve or platform has been strongly advocated during specimen extraction in order to prevent tumor fragmentation

and seeding. The first case of a radical laparoscopic sigmoid resection with transvaginal assistance going beyond transvaginal extraction was performed in a patient with a T3N1 sigmoid cancer.¹ Adequate oncologic resection was achieved, and the patient was discharged on the fourth postoperative day without any intraoperative or postoperative complications reported.² Another case of a transvaginal total colectomy was performed with transvaginal specimen extraction, delivery of the anvil, and double-stapled ileorectal anastomosis in a patient with familial adenomatous polyposis (FAP) and a T3N1M1 sigmoid cancer. This patient was found to have good perioperative and oncologic outcomes.³

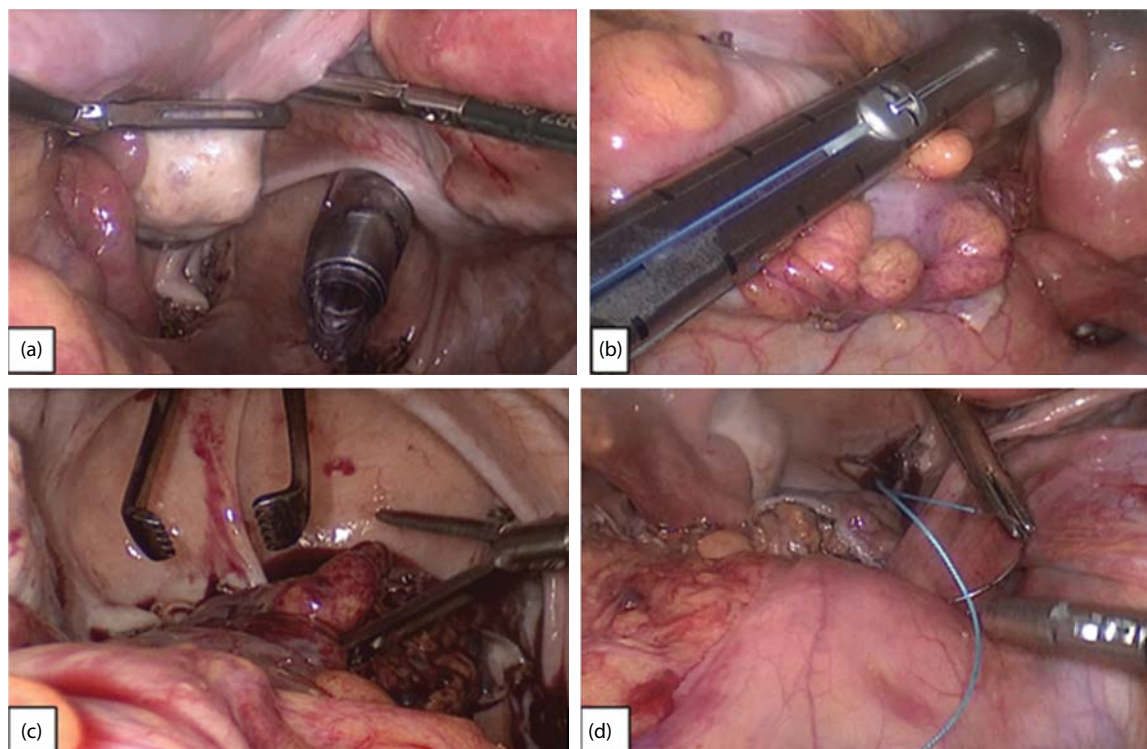


Figure 28.1 Transvaginal NOTES sigmoid colectomy with suture rectopexy for full-thickness rectal prolapse. Following laparoscopic circumferential mobilization of the sigmoid colon and rectum all the way down to the pelvic floor, transvaginal access was obtained using a 12 mm trocar under direct laparoscopic visualization (a). The rectosigmoid was transected with a laparoscopic stapler inserted through the vaginal trocar (b). The sigmoid colon was exteriorized transvaginally (c). Suture rectopexy was performed with sutures placed through the vaginal trocar (d).

Transvaginal NOSE and assistance are more technically challenging to perform during right colectomy than left colectomy, as it requires laparoscopic intracorporeal anastomosis following colonic transection and specimen extraction.² While it can be offered to female patients undergoing right colon resection for a variety of pathologies (benign and malignant), the benefits of this approach must be weighed against the risks of possibly longer operative time and higher risks of procedural complications, especially when considering the impact of the surgeon's learning curve to master intracorporeal anastomotic techniques. A retrospective study comparing 34 patients who underwent laparoscopic right colectomy with standard transabdominal extraction to 34 patients who underwent transvaginal extraction with intracorporeal anastomosis for right colon cancer demonstrated no significant differences in operative time (171 minutes versus 147 minutes, $p = 0.09$), blood loss (43 mL versus 32 mL, $p = 0.37$), or perioperative morbidity (11.8% versus 38.2%, $p > 0.05$), respectively. Conversion to an abdominal extraction site was required in two NOSE patients due to a large specimen size (6%). Patients in the NOSE group reported significantly lower pain scores on POD1 and POD3 and had a shorter length of postoperative stay (length of stay 7.9 days versus 8.8 days, $p = 0.003$) than the transabdominal extraction group. Cosmetic results were

superior in the NOSE group relative to the transabdominal extraction group, and there was no report of dyspareunia in the NOSE group that had resumed sexual activity.² While this series did not demonstrate prolonged operative time or increased intraoperative or postoperative complications with the NOSE technique, it did not address the impact of the surgeon's experience with intracorporeal anastomotic techniques on outcomes. Generalizability of this data is dependent on surgeon experience, and training in these techniques is not yet mainstream.

Another study of transvaginal and transanal NOSE colectomy included 26 transvaginal specimen extractions following laparoscopic right, left, sigmoid colectomies and low anterior resections (LARs) for benign and malignant indications. Franklin et al. reported a mean operative time of 159 ± 27.1 minutes, estimated blood loss was 83.5 ± 14.4 mL, and the mean length of stay was 5.5 ± 2.5 days.¹ While there were no postoperative complications reported, two injuries (7.7%) to the rectum and sigmoid colon were noted to occur during transvaginal NOSE procedures. And in the largest registry of transrectal and transvaginal NOTES colorectal resections, 86.9% of all 122 reported cases of transvaginal NOTES colectomy were performed with sigmoid resection, while 4.1% were performed for right colectomy or ileocollectomy. Indications for resection with

transvaginal assistance included colon cancer in 11% of all cases. A 4.1% rate of conversion to laparoscopy was reported with a 2.3% and 12.3% incidence of intraoperative and postoperative complication rate, respectively.⁴

Table 28.1 summarizes all published studies on transvaginal NOTES colectomy with sample size ranging from 1 to 122 cases. Overall morbidity across series ranged from 0% to 100% in the smallest case reports. Conversion to abdominal extraction was common and reflected the large specimen size that precluded safe extraction through the vagina. The use of a protective wound retractor or retrieval bag for specimen extraction through the posterior colpotomy was frequently reported but was not universal. While dyspareunia was only assessed in a small subset of transvaginal NOTES colectomy series,⁵ other NOTES series including transvaginal cholecystectomy and appendectomy series have reported no evidence that transvaginal procedures were associated with dyspareunia or sexual dysfunction.^{3,6,7}

Despite nearly 400 cases of transvaginal NOTES colectomy cases with good perioperative and oncologic outcomes being published over the last 10 years, transvaginal NOSE and NOTES colorectal surgeries have not become as widely adopted as the transanal counterpart. Similar to the trend noted with NOTES transvaginal cholecystectomy, this may be largely due to a perceived yet unsupported risk of dyspareunia and negative impact on sexual function and fertility and fecundity. Most importantly, while the published data support the feasibility and safety of transvaginal NOTES colectomy, the lack of significant benefits of this approach over standard minimally invasive approaches has been a major limiting factor in widespread adoption.⁸

TRANSANAL NOTES EXPERIENCE

Over the last two decades, colorectal NOTES has evolved from transanal endoscopic surgery (TES) and NOSE to hybrid and pure transanal NOTES. While hybrid NOTES procedures combine transabdominal minimally invasive surgery with transanal endoscopic assistance, pure transanal NOTES uses transanal access as the primary route to perform complex colorectal procedures. Transanal NOTES colectomy provides direct and inline access to colorectal pathologies, which is greatly enhanced with the use of specialized multiport transanal endoscopic platforms.

Transanal NOSE

Over the last two decades, transanal specimen extraction during laparoscopic and robotic colorectal operations has gained popularity.^{9–11} Benefits of this strategy include avoidance of an abdominal extraction site with improved cosmetic results and reduced incisional pain, wound infection, and incisional hernia risks. Disadvantages include the added steps required, increased operating time, and technical complexity if performed for lesions located proximal

to the mid- or low rectum, specifically those that require intracorporeal transection of the colon and preparation for intracorporeal stapled anastomosis. The main technical challenge of transanal specimen extraction that has limited wide adoption of this strategy is related to the planned level of colon or rectal transection. Due to the proximity of the rectum to the anorectal junction, specimen extraction through the mid- or low rectum followed by low stapled colorectal anastomosis or handsewn coloanal anastomosis is less technically demanding than transcolonic specimen extraction. While the colon can be easily transected laparoscopically, the technical challenge is in the preparation for stapled colo-colonic anastomosis. The additional steps include (1) creation of a proctotomy; (2) transanal extraction through (3) creation of a colotomy along the proximal colon for insertion of the anvil; and (4) suture, pursestring, or stapled closure of the colotomy and the proctotomy created in preparation for (5) stapled colorectal anastomosis. Each of those added steps cumulatively increase the technical complexity and operating time, as well as the potential risk for complications, particularly along the surgeon's learning curve. In addition, there have been concerns regarding fecal and tumor spillage that could result from transecting the bowel intracorporeally.

With respect to techniques during laparoscopic resections with transanal extraction, different types of transanal strategies have been described including variations in laparoscopic assistance (multiple trocars, single incision, and robotic access) and different types of transanal extraction platforms including rigid or disposable transanal endoscopic ports, sleeves, and bag retrieval systems, especially when large specimens are being extracted.¹² Different techniques for colorectal transection have been described (**Table 28.2**). Some studies describe occlusion of the rectum first with bowel clamps or pursestring sutures followed by transection of the bowel in order to prevent fecal spillage. Others describe stapling the colon or rectum followed by cutting the staple line open, and some surgeons perform rectal stump washout before transecting the bowel in order to prevent tumor spillage. In addition, different strategies for anvil insertion, through an abdominal incision, or through a transanal platform, have been described. **Figure 28.2** depicts operative images from a transanal NOSE for colectomy.

With experience, operative time and perioperative morbidity are exceedingly low. The largest transanal NOSE colectomy series by Franklin in 2013 reported the outcomes of 277 transanal specimen extractions for benign and malignant colorectal pathology requiring right, left, and sigmoid colectomy as well as LAR.¹ The average operative time was 165 minutes, and blood loss was 88 mL. The group undergoing transanal extraction suffered no intraoperative complications and 10 (3.6%) major postoperative complications, including one bowel obstruction, three anastomotic leaks, and six occurrences of postoperative fecal incontinence. Minor postoperative complications occurred at a rate of 5.4% with two wound infections, seven reports of

Table 28.2 Transanal specimen extraction studies

Series	Year	<i>n</i>	Type of operation	Pathology	Number of ports	Transanal protection	Duration of surgery (minutes)	Morbidity (<i>n</i>)	Length of stay (days)
Akamatsu ⁶⁶	2009	16	Sigmoid resection	Malignant	4	None	180 (137–257)	Wound infection (1)	11 (8–14)
Cheung ⁶⁷	2009	10	Sigmoid resection	Malignant	5	Transanal endoscopic operation	127.5 (105–170)	None	7 (4–18)
Saad ⁶⁸	2010	8	Sigmoid resection	Benign and malignant	4	McCarteny tube	95–180	None	4–8
Lamade ⁶⁹	2010	3	Restorative proctocolectomy	Inflammatory bowel disease (ulcerative colitis)	1 + transvaginal assist	None	NS	None	11,12 and 14
Leroy ³³	2011	16	Sigmoid resection	Diverticulitis	3	None	120.9 (41.9)	Epigastric pain (1) and fever (3)	6.1 (2.4)
Nishimura ⁷¹	2011	16	Sigmoid resection	Malignant	5	Wound retractor	241 (188–309)	Leakage (1)	6 (4–16)
Wolthuis ⁷²	2011	21	Sigmoid resection	Endometriosis	4	Retrieval bag	90 (85–105)	Urinary tract infection (1)	6 (5–7)
Wolthuis ⁷³	2011	21	Sigmoid resection	Benign and malignant	4	Retrieval bag	05 (90–110)	Leakage (1)	6 (5–7)
Hara ⁷⁴	2011	9	Sigmoid resection	Malignant	4	None	293 (220–342)	None	NS
Costantino ⁷⁵	2012	17	Sigmoid resection	Benign	3	None	122 (36.5)	Bleeding (1), fever (2), abscess (1), leakage (1)	7.2 (4.9)
Christoforidis ⁷⁶	2013	11	Sigmoid resection	Benign	4	Camera sleeve	200 (120–360)	Abscess (1), leakage (1), and trocar hernia (1)	6 (4–33)
Franklin ¹	2013	277	Sigmoid and low anterior resection	Benign and malignant	4	Retrieval bag	164.7 (47.5)	Leakage (3)	6.9 (2.8)
Fuchs ¹⁶	2013	15	Sigmoid resection	Benign	3	Transanal endoscopic applicator	131 (55–184)	Bleeding (1), ileus (1)	NS
Han ⁷⁷	2013	34	Sigmoid and low anterior resection	Malignant	5	Transanal endoscopic microsurgery and bag	151.6 (125–185)	Leakage (6)	9 (7–66)
Bulian ⁴	2014	17	Sigmoid resection, proctocolectomy	Benign and malignant	3 (1–4)	NS	205 (87–600)	11.8% (2)	11.0 (5–99)
Lamm ⁶⁵	2015	40	Sigmoid resection	Diverticular disease	NR	Wound protector	170 (136–202)	10% complication rate (sepsis [2])	6 (5–8)

Note: NS, not stated; NR, not reported.

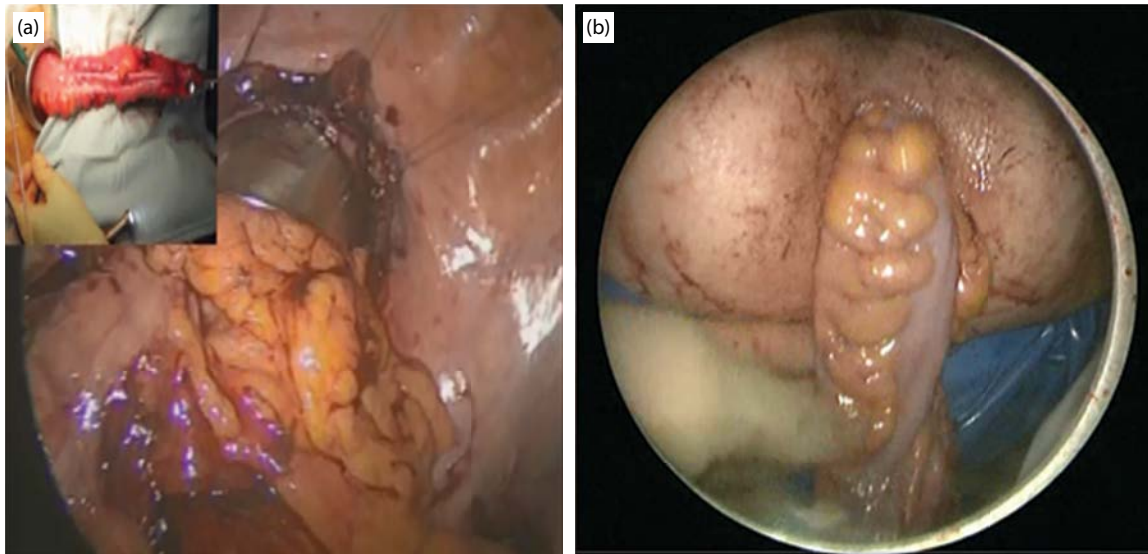


Figure 28.2 Transanal NOSE during sigmoid colectomy for cancer. Following laparoscopic mobilization of the sigmoid and proximal rectum, the upper rectum was transected with a stapler, the rectum stump was irrigated with betadine, and the staple line was excised. The TEO transanal platform was inserted transanally through the open rectal stump (a), and the sigmoid colon was exteriorized transanally (b).

postoperative ileus, and six urinary tract infections. The average length of stay (LOS) was 6.9 days.³

These findings were supported in a small randomized trial in 2013 comparing outcomes of 35 patients undergoing hybrid NOTES colectomy versus 35 patients undergoing standard laparoscopic left colectomy with a 4–6 cm transverse suprapubic extraction incision for left-sided colonic tumors 4 cm or less in size.¹³ Following laparoscopic left colon mobilization, the colon was occluded below the tumor, the rectum was washed out and transected, and the proximal colon was pulled through transanally and transected followed by introduction of the anvil into the peritoneal cavity through a rigid TES platform and insertion into the proximal colon through a colotomy. This was followed by stapled intracorporeal anastomosis. Minimal or no differences in operative time (105 versus 100 minutes), blood loss (30 versus 30 mL), or LOS (5 versus 5 days) were noted between the groups. There were no major complications in either group, but wound infection was noted in four versus zero patients in the conventional laparoscopic versus NOSE group ($p = 0.005$). The maximum first week pain scores were significantly lower in the NOSE group ($p = 0.017$). This study confirmed surgeons' expectations that NOSE combined with standard laparoscopic left colectomy might further improve outcomes with respect to reduced wound-related complications and incisional pain. However, this is the only randomized trial comparing laparoscopic left colectomy with transanal specimen extraction versus standard transabdominal specimen extraction, the sample size was small, and the study was subject to tumor and patient-related selection biases.

Overall, despite the published data demonstrating the safety and benefits of combining NOSE with standard

laparoscopic left colectomy and LAR in particular, transanal specimen extraction has not routinely been incorporated into routine laparoscopic or robotic practice, likely as a result of the learning curve required to achieve expertise and the need for and cost of additional staff and specialized equipment. It is important to note that in order to exteriorize the proximal colon transanally, extended mobilization of the colon is usually needed in addition to complete splenic flexure takedown, inferior mesenteric vein transection, and potential disruption of the colonic mesentery. Finally, NOSE is contraindicated in patients with bulky specimens in whom transanal extraction is neither safe nor feasible, and may be more difficult to achieve in patients with higher body mass index with significant visceral adiposity and foreshortened mesentery.

Transanal NOTES colectomy

Since Franklin's 1993 original description of using the transanal route for specimen extraction during laparoscopic left colectomy,¹² subsequent evolution in transanal NOTES was inspired by the large clinical experience with transanal endoscopic microsurgery (TEM) popularized by Buess in the early 1980s.¹⁴ The TEM multiport endoscopic metal platform has enabled submucosal or full-thickness endoscopic resection of rectal tumors followed by suture closure of the rectal defect. Current transanal platforms, globally referred to as transanal endoscopic surgery (TES) include the rigid and reusable TEM (Richard Wolf, Knittlingen, Germany) and transanal endoscopic operation (TEO) (Karl Storz, Tuttlingen, Germany) platforms, as well as the more pliable and disposable transanal minimally invasive

surgery (TAMIS) platforms, which include SILS (Medtronic, Mansfield, Massachusetts) and Gelpoint Path (Applied Medical, Inc., Rancho Santa Margarita, California). In combination with high-definition (HD) laparoscopic cameras, standard or high-flow CO₂ insufflators, and smoke evacuation systems, excellent endoluminal distention and visualization can be achieved. TES has enhanced the ability to resect rectal lesions using minimally invasive techniques with superior outcomes relative to standard transanal excision with respect to margin positivity, specimen fragmentation, and local recurrence.¹⁵

Nearly three decades after the original description of TEM, experimental work in animals and human cadavers led to investigating the feasibility of a transanal NOTES approach to perform pure and hybrid colorectal resections using TEM and other commercially available TES instrumentation. In parallel with development of pure and hybrid transanal NOTES rectosigmoid resections, these efforts eventually led to transanal endoscopic proctectomy and transanal total mesorectal excision (taTME).

Going beyond using transanal access only for specimen extraction, Fuchs et al. have described using a transanal endoscopic platform to perform critical steps of colectomy procedures including introduction of the anvil, bowel transection with a linear stapler, specimen retrieval, and stapled anastomosis. In a series of 15 patients undergoing transanal hybrid NOTES sigmoid resection or subtotal colectomy for benign disease (pelvic floor disorders, full-thickness rectal prolapse, diverticulitis, and slow-transit constipation), one patient required conversion to full laparoscopy. Mean operative time was 131 minutes (range 55–184), and only one postoperative complication was reported (hemorrhage) with no reoperations or deaths. This study demonstrated that transanal assistance during colorectal resections can be safely used to reduce the number and size of abdominal trocars.¹⁶

Meanwhile, Whiteford et al. first reported pure transanal NOTES rectosigmoid resection in three human cadavers using the TEM platform in 2007, and subsequent studies cemented the feasibility and safety of this approach as well as potential benefits in large human cadaver series and swine survival studies.^{17–19} The largest cadaver series ($n = 32$) of transanal NOTES rectosigmoid resection demonstrated that although pure transanal NOTES rectosigmoid resection was feasible, it was technically more challenging due to difficulty for the TEM platform to negotiate the steep angle of the sacral promontory, and the short length of laparoscopic instruments used transanally. As a result, a pure transanal NOTES approach resulted in a shorter segment of rectosigmoid colon specimen and a higher rate of bowel perforations than the hybrid transanal NOTES approach with laparoscopic assistance.¹⁵ With respect to the learning curve, operative time was shorter (5.9 versus 4.9 hours; $p = 0.13$) and specimen length was longer (28.2 versus 57.9 cm; $p = 0.001$) after the first five cases. This suggests that there is a learning curve to performing these operations.¹⁹

Ultimately, this innovative approach progressed to clinical applications with the first human case of a rectosigmoid resection using hybrid taTME. This operation was first performed by Sylla and Lacy with subsequent rapid worldwide adoption of hybrid taTME in the management of benign and malignant rectal pathologies.²⁰ Overall, hybrid transabdominal and transanal techniques during minimally invasive colorectal resections have continued to flourish, and this evolution has been facilitated by the introduction of novel and easily accessible transanal endoscopic platforms and instrumentation that have enabled transanal endoluminal access, exposure and visualization, transluminal dissection, and safe creation of colorectal and coloanal anastomoses.

TRANSANAL TOTAL MESORECTAL EXCISION

TaTME is a particularly attractive approach for low rectal cancer in obese male patients with a narrow pelvis, and in whom sphincter preservation is considered. In such cases, exposure of the deep pelvis and access to the pelvic floor is severely compromised regardless of whether TME is attempted laparoscopically or robotically. In this high-risk group, conversion rates to open surgery have remained high, as have rates of incomplete TME, reflecting the formidable challenge of negotiating surgical instruments and surgical staplers in the narrow male pelvis. This is also reflected in the persistently high rate of abdominoperineal resection (APR) for patients with tumors located ≤ 6 cm from the anal verge.^{21,22} By facilitating access to the rectum and mesorectum, puborectalis, perirectal tissues, prostate, and vagina, taTME is rapidly becoming a preferred alternative for TME in this patient population. With the improved exposure achieved through TES platforms, excellent visualization of key anatomic structures can be achieved while avoiding the constraints of the narrow pelvis. **Figure 28.3** depicts an operative image from a taTME operation using the TEO platform. Several early case reports and small case series demonstrated the feasibility and safety of this approach, which has led to rapid adoption of taTME, as reflected by a rapidly growing number of larger series.^{23,24} The dissection steps for taTME are illustrated in **Figure 28.4** with the final specimen captured in the image of **Figure 28.5**.

Hybrid transanal TME

Since the first report of a hybrid taTME case in 2009, over 700 taTME cases have been published to date, and the LOREC taTME registry recently reported the results of the first 720 cases entered into this international registry between July 2014 and December 2015.²⁵ Based on the results from the taTME registry, 88.1% of all taTME cases were performed for preoperatively staged T1–T3 rectal cancer (94.5%) and N1/N2 disease (48.2%), while the remainder was performed for benign disease. The mean patient body mass index was

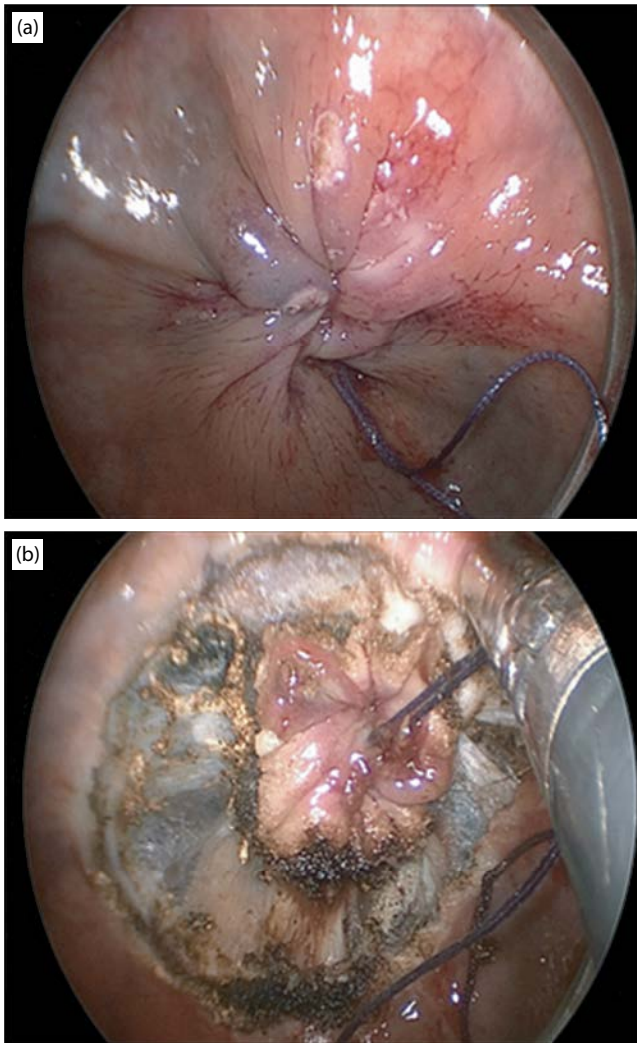


Figure 28.3 Transanal TME for a tumor of the mid-rectum in a female patient. Following insertion of the TEO transanal platform, the rectum was occluded with a pursestring suture below the tumor (a). The rectal mucosa was first scored circumferentially with monopolar cautery just distal to the pursestring suture followed by full-thickness dissection of the rectal wall (b).

26.5 ± 4.3 (range, 16.5–42.7). LAR with sphincter preservation was performed in 90% of patients, and in 34.4%, either mucosectomy or partial or complete intersphincteric resection (ISR) was performed in order to achieve negative margins. The median distance of the tumor from the anal verge was 6 cm (range, 0–13 cm). The conversion rate from a perineal approach to an abdominal procedure was 2.8%, and 6.3% of laparoscopic abdominal procedures were converted to open surgery. With respect to oncologic results, the median lymph node harvested was 15 (range, 0–70), R0 resection was achieved in 97.3% with a 2.4% rate of positive circumferential radial margins (CRMs), and incomplete TME was observed in 4.1% with a 2% incidence of rectal perforation. There was a 1.5% incidence of intraoperative organ injury including urethral or bladder injury in seven cases

(1%). The overall mortality rate was 2.4% with 32.6% overall morbidity including anastomotic leaks (6.7%), pelvic abscess (2.4%), reoperation (6.1%), and hospital readmission (6.9%). The median LOS was 8 days (range, 2–97).

Separate from the self-reported LOREC taTME registry, 13 taTME case series with a sample size greater than 15 patients (range 16–140) have been published to date totaling 577 patients. At a mean follow-up ranging from 5 to 32.6 months, 10 of these studies reported local recurrence in 14 cases and distant recurrence in 39 cases. Time to recurrence ranged from 3 to 24 months as summarized in [Table 28.4](#).

With regard to functional outcomes following taTME, only 5 of the above 13 larger sample sized taTME series reported the functional status of patients postoperatively. With follow-up ranging from 5 to 32 months, all five studies reported some variable degree of defecatory dysfunction with an average Wexner score at 6.9.^{3–18}

Overall, the international experience with taTME remains preliminary and based on small to larger single institutional cases series with no randomized trial comparing taTME with open or laparoscopic TME. There have been five retrospective studies that have compared outcomes of matched cohorts of patients who underwent taTME versus laparoscopic TME.^{26–30} Fernandez-Hevia et al. retrospectively case-matched 37 cases of laparoscopic-assisted taTME with 37 cases of laparoscopic TME for rectal cancer and demonstrated no significant differences with respect to quality of the mesorectal specimen, lymph node harvest, resection margins, or intraoperative complications.²⁶ They also demonstrated comparable 30-day postoperative complications, but a statistically significant lower readmission rate in the taTME group (2% versus 6%).²⁶ Velthuis et al. retrospectively matched 25 cases of laparoscopic-assisted taTME with 25 cases of laparoscopic TME, and interestingly, they found that taTME was associated with a significantly higher rate of complete mesorectum than laparoscopic TME (92% versus 72%).²⁷ The studies by de'Angelis, Perdawood, and Chen each retrospectively compared laparoscopic-assisted taTME with laparoscopic TME, demonstrating shorter operative times and hospital stays with no differences in intra-/postoperative complications and oncologic outcomes.^{28–30} Currently, the COLOR III trial is in preparation, which will compare standard laparoscopic TME versus transanal TME.³¹

A recent publication described the impact of taTME training courses in cadaveric models among 52 surgeons in the United Kingdom and United States between 2013 and 2015.³² Based on completed postcourse surveys, 81% of the trained surgeons had adopted taTME in their clinical practice, and 81% were able to perform the operation with complete or near complete specimen quality during the training cadaver course. The consensus among taTME trainers and experts echoed in this publication states that surgeons contemplating adoption of taTME should not only have prerequisite expertise in minimally invasive TME and TES but should also be familiar with intersphincteric resection

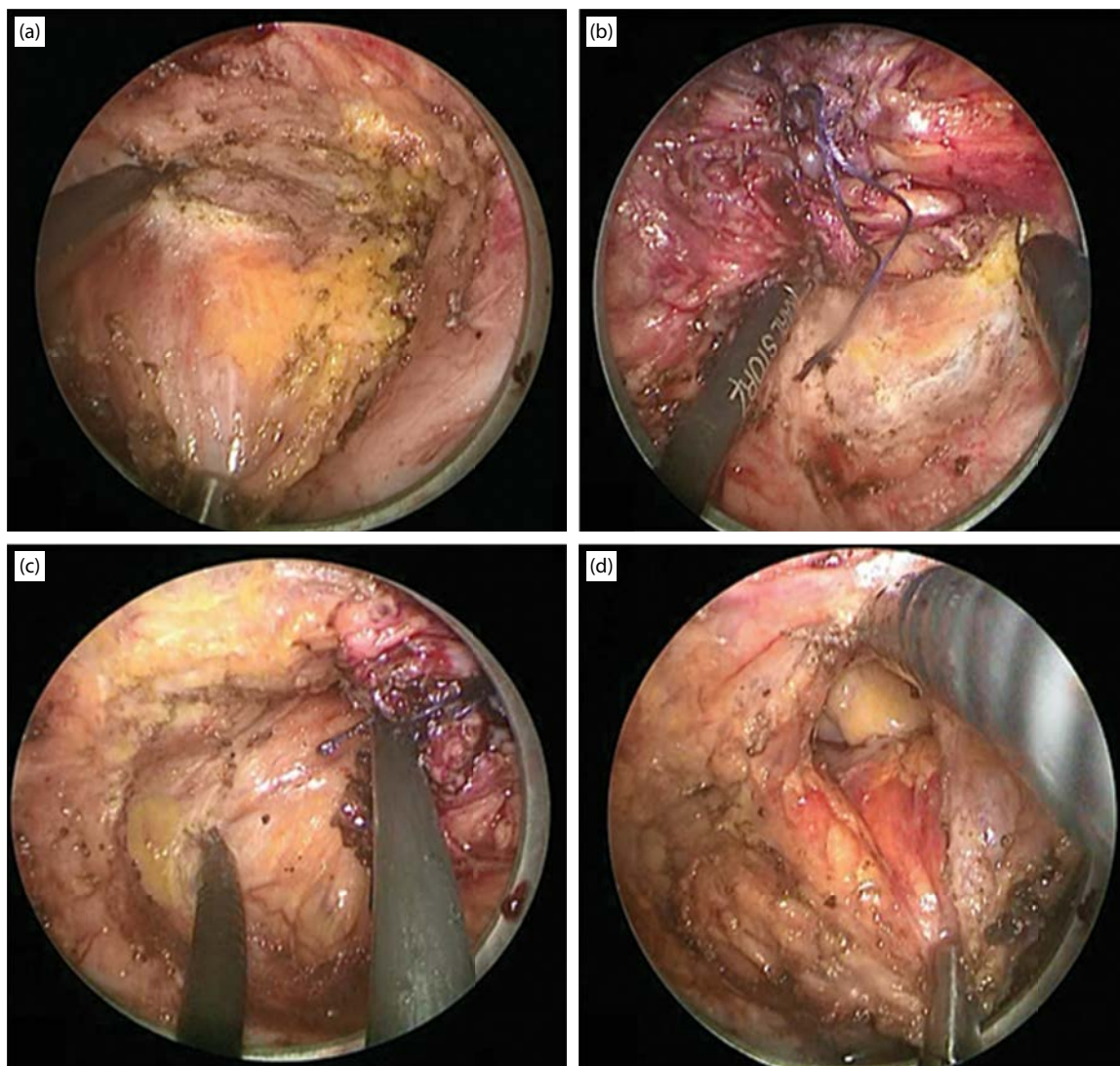


Figure 28.4 Dissection steps during transanal TME. Circumferential dissection of the rectum and mesorectum was extended superiorly along the anterior rectovaginal plane (a), posteriorly between the mesorectal fascia and the sacrum (b), and laterally, off the pelvic sidewall (c). Anteriorly, dissection was carried out until the peritoneal reflection was reached and divided, and transanal and abdominal planes of dissection were connected (d).

techniques, and undergo hands-on cadaver training in the context of a structured training curriculum.³²

Pure taTME

The overall experience for a pure transanal approach to TME without laparoscopic assistance is sparse but growing. Leroy and Zhang described the first two cases of a pure taTME in 2013 demonstrating that it was feasible and safe for mid- to low-lying rectal cancer.^{33,34} Since then there have been 23 cases of pure taTME reported with good short-term oncologic outcomes (mean lymph node harvest 6–17, negative CRM, and distal margins).^{35,36} In the study by Chouillard et al., 10 out of 16 taTME cases

were performed in pure fashion in eight women and two men, with no ileostomy or conversion to laparoscopy.³⁵ In their series of 20 taTME cases with and without abdominal assistance, 15 were performed in pure fashion in nine men and six women; however, conversion to laparoscopy was required in four males due to prostatic and urethral injury and bleeding, suggesting that the procedures were technically easier to perform in females.³⁶ Finally, Marks et al. also recently reported their small series of four attempted NOTES transanal TME resections in which procedures were completed in a pure NOTES fashion in two of four cases, with the other two cases requiring abdominal assistance with colonic mobilization, splenic flexure takedown, and inferior mesenteric artery (IMA)/IMV vessel transection.³⁷ Overall, as described in the



Figure 28.5 TME specimen. Following transanal exteriorization of the rectosigmoid, the colon was divided, followed by stapled colorectal anastomosis.

initial cadaveric series, while clinical transanal NOTES TME is feasible in a limited to a small number of carefully selected patients, until significant improvements in instrumentations and platforms occur, taTME should be performed with transabdominal assistance for safety purposes specifically in order to maximize exposure to critical structures and minimize the risk of organ injury.

INDICATIONS FOR TRANSANAL NOTES COLECTOMY

Transanal NOTES segmental and total colectomies have been performed for colon cancer¹³ as well as for benign disease including rectal prolapse, diverticulitis, and

constipation/pelvic floor disorders.¹⁶ Transanal NOTES proctectomy with or without sphincter preservation, and with or without TME, has been performed for both benign and malignant pathologies. Common indications for completion proctectomy include inflammatory bowel disease (IBD)–related complications involving the retained rectal stump, while indications for transanal NOTES APR include IBD, fecal incontinence, rectal stenosis, radiation proctitis, anastomotic complications following proctectomy, complex refractory fistula, and rectal cancer not eligible for sphincter salvage. Benign and malignant indications for transanal NOTES proctectomy with sphincter preservation, with or without mesorectal dissection, include restorative proctocolectomy for ulcerative colitis and FAP, advanced adenomas, and rectal cancer (Tables 28.3 and 28.4).

With respect to rectal cancer, indications for taTME are similar to that of laparoscopic and robotic TME with respect to tumor stage, namely, node positive or negative T1 rectal cancer with high-risk histologic features, T2 and T3 tumors without threatened CRM on preoperative pelvic magnetic resonance imaging. T4 tumors and those with threatened CRM may become eligible for taTME if significant downstaging or complete clinical response is demonstrated following full-course neoadjuvant treatment. Hence, careful tumor staging is necessary prior to consideration for taTME, including computed tomography scans of the chest, abdomen, and pelvis; pelvic magnetic resonance imaging; carcinoembryonic antigen CEA level; proctoscopy; and digital rectal assessment. As reflected in the LOREC taTME registry, the large majority of taTME cases are performed for low and mid-rectal tumors, with 62% of cases performed for tumors ≤ 6 cm, 37% for tumors 7–10 cm and only 1% performed for tumors larger than 10 cm from the anal verge in the registry.²⁵ This reflects the patient population that benefits the most from this transanal approach, namely, obese male patients with a narrow pelvis, enlarged prostate, and low rectal tumors. For tumors located less than 2 cm from the dentate line, as is standard of care for other TME approaches, taTME is combined with partial or complete ISR in order to achieve sphincter preservation while ensuring negative radial and distal margins.

With increasing experience and confidence, surgeons are currently exploring primary transanal approaches for redo proctectomy and colorectal anastomosis. In a recent study by Borstlap et al., a transanal approach with a TAMIS platform was used to salvage patients with a persistent

Table 28.3 Transanal endoscopic proctectomy for benign disease

Study	Year	n	Pathology	Platforms/operation	Operative success	Complications
Liyanage ⁷⁸	2013	12	Inflammatory bowel disease, radiation proctitis, extensive carpeting adenomas	Transanal endoscopic microsurgery platform	8 pure transanal	Delayed healing (4), colocutaneous fistula (1)
Bremers ⁷⁹	2013	9	Inflammatory bowel disease (6), Lynch syndrome (1), collagenous colitis (1), anastomotic leakage (1)	Transanal endoscopic microsurgery platform	1 mini-laparotomy	Postoperative abscess (1)

Table 28.4 Transanal total mesorectal excision for rectal cancer

Study, year	n	Intraoperative complications	Postoperative complications, overall (specific n)	Circumferential radial and distal margins	Total mesorectal excision quality	Lymph nodes collected	Long-term oncologic outcomes
Rouanet ⁴⁷	30	Conversion 7% (2), urethral injury (2), air embolism (1)	30% (bowel obstruction [2], peritonitis [1], sepsis [1], transient urinary disorder [2], reoperation [2])	13.3% positive CRM, 0.9 cm distal margin	100% complete	13	NS
Chouillard ³⁵	16	Conversions 6.25%	18.8% (small bowel obstruction requiring reoperation [2], and pelvic abscess requiring reoperation [1])	0% positive CRM, 3.6 cm distal margin	100% complete	21	No recurrence at 9-month follow-up
Buchs ⁸⁰	20	Conversions 15% (3)	30% (severe complications: 10% [pelvic hematoma and late leak])	5.9% positive CRM, 2.14 cm distal margin	94.1% complete or near complete	23	One distal recurrence (median follow-up 10 months)
Lacy ⁸¹	140	None	24.2% (severe morbidity 10%)	Positive CRM 6.4%	97.1% complete 2.1% near complete	14.7 ± 7	2.3% local recurrence rate and 7.6% systemic recurrence at 15 months mean follow-up
Tuech ⁸²	56	Conversion 7.3% (due to obesity [2], adhesions [1])	26% (anastomotic leak [3], pelvic sepsis without leak [3], urinary retention [5], blood transfusion [2], cerebral infarction [1])	5.4% positive CRM, 1 cm distal margin	84% complete, 16% near complete	12	NS
Muratore ⁸³	26	None	26.90%	0% positive CRM, 1.9 cm distal margin	88.5% complete	12	NS
Veltcamp ⁸⁴	80	Conversion to open (4)	39% (severe morbidity 12%)	Positive CRM (2)	88% complete and 9% near complete	NS	Local recurrence in two patients with 2.5-year follow-up
Chen ³⁰	50	Conversion (1), complications (3)	20% (4% reoperation rate)	NS	NR	16.7 ± 8	NS
De'Angelis ²⁸	32	No complications, conversion (1)	25% (6.2% severe complications)	3.1% positive CRM, 2.1 cm distal margin	84% complete, 9.4% nearly complete	17.1	1-year mean follow-up with 6.2% recurrence
Kang ³⁶	20	No complications, conversions (4)	20% morbidity (urethral injury [1], urinary retention [2], anastomotic leak [1], anastomotic hemorrhage [1])	No positive CRM, distal margins all negative	100% complete	12 (1–20)	NS
Perdawood ²⁹	25	Bleeding (2), conversion (0)	Anastomotic leak (2), urinary dysfunction (4)	CRM positive (1), distal margin 3.9 cm	80% complete, 20% nearly complete	21 (9–42)	NS
Burke ⁴⁹	50	Conversion (2.2%), 6% intraoperative complications	36% morbidity rate	CRM positive (4%)	98% complete or nearly complete	18 (12–24)	Median follow-up 15 months (two local recurrences and eight distant recurrences)

(Continued)

Table 28.4 (Continued) Transanal total mesorectal excision for rectal cancer

Study, year	n	Intraoperative complications	Postoperative complications, overall (specific n)	Circumferential radial and distal margins	Total mesorectal excision quality	Lymph nodes collected	Long-term oncologic outcomes
Serra-Araci ⁷⁰	32	No conversions	Morbidity rate 31.3%, surgical site infection 9.4%, anastomotic leak 9.4%	CRM positive (0), distal margin 2 cm	93.75% complete, 6.25% nearly complete	15 (7–41)	NS
Buchs ⁴⁸	40	No intraoperative complications, conversions (3)	16 complications (68.6% minor)	95% R0 resection margins	97.5% complete or nearly complete	20	11 months follow-up with no local recurrence and 15% distant metastasis
Fernandez-Hevia ²⁶	37	None	32% (anastomotic leak [2], collection [1], hemorrhage [1], urinary retention [1], ileus [4], ascites [1], fever [1], high ileostomy output [1], reoperation [3])	0% positive CRM, 2.8 cm distal margin	91.9% complete	14	NS
Denost ⁴⁴	50	Conversion 4%	32% (no mortalities, severe morbidity 12%, leak 2%, reoperation 4%)	4% positive CRM, 1 cm distal margin	70% complete, 18% near complete	17 (2–30)	NS
Rasulov ⁴³	22	Conversion (1)	27% (no severe complications, urinary retention [3])	23% positive distal resection margin, 5% positive CRM	68% complete, 14% near complete	17	NS

Note: CRM, circumferential margin; NS, not stated; TME, total mesorectal excision.

presacral sinus and other LAR- or ileoanal J-pouch-related anastomotic complications such as stenosis, persistent presacral sinus, or recurrent cancer.³⁸ Seventeen patients underwent anastomotic reconstruction¹⁴ or completion proctectomy.³ Procedures were performed using a pure transanal approach in two patients, and all other procedures were performed in a hybrid fashion. All procedures were successful but technically complex as reflected by an average operative time of 265 minutes and a 14% anastomotic leak rate and a 24% incidence of pelvic sepsis requiring reintervention.³⁸

Platforms and equipment for transanal NOTES colectomy

Today pure and hybrid transanal NOTES colectomy is facilitated by the recent addition of disposable transanal platforms to the market. The abdominal portion of the cases requires standard laparoscopic or robotic instruments using multiport or single-port access. Laparoscopic abdominal teams should be equipped with HD video monitors located on the right and left of the patient, while the transanal team should have a video monitor with a moveable screen on a swivel located between the legs facing the transanal surgeon/team at eye level but not obstructing the operative field of the abdominal team.

Transanal procedures are performed using standard anorectal trays with plastic or metal anoscopes, monopolar cautery and a laparoscopic bipolar device, laparoscopic suction and irrigation, and a high-flow insufflator and smoke evacuation system like the AirSeal system (SurgiQuest, Milford, Connecticut), but other high-flow insufflators are available on the market. For completion of colorectal or coloanal anastomoses, EEA staplers and the Lonestar retractors (Lonestar Medical Products, Inc., Houston, Texas) are commonly used. A common design feature among all transanal platforms used for transanal NOTES colectomies is a diameter ranging from 3.5 to 4 cm and a detachable and airtight multiport faceplate or cap that allows intraluminal insertion of a video-scope and two to three laparoscopic instruments, staplers, or suturing devices ranging in size from 5 to 10 mm. Rigid platforms, including the TEM and TEO platforms, allow a single transanal operator to be seated in between the patient's legs since the videoscope is anchored to the platform, which is in turn anchored to the operating room table using a locking arm. The TEM platform is equipped with a three-dimensional operating microscope but is also compatible with a standard HD laparoscopic camera, videoscope, and laparoscopic video tower, as is the TEO platform. TAMIS procedures require a dedicated assistant to hold the camera, which ideally consists in a bariatric length 10 mm HD camera. The most commonly used TAMIS platform includes the GelPoint Path and the SILS platforms. Other transanal platforms have been described during transanal NOTES colectomy including a rigid transanal endoscopic applicator (TEA).¹⁶ Most recently, surgeons have introduced the robot transanally

through TAMIS platforms in the hope of improving intraluminal visualization with three-dimensional optics, and the precision of the dissection using the robotic arms. While the experience with transanal endoluminal robotics is still preliminary, several small series have demonstrate the feasibility and preliminary safety of this approach for transanal proctectomy of the use of transanal platforms with transabdominal robotic resections.^{9,39,40}

Setup and procedure: Transanal NOTES proctectomy

NOTES colectomy and taTME procedures are technically complex operations, and it is critical that the teams performing these procedures are experienced in minimally invasive surgical techniques and TES. Teams adopting taTME in particular should also be experienced in minimally invasive TME for rectal cancer and be familiar with coloanal anastomotic techniques as well as intersphincteric resection. Prior training in human cadaver models is a prerequisite, and proctoring of the first cases is also strongly recommended. With respect to laparoscopic colectomy with transanal NOSE and transanal NOTES colectomy, the surgical techniques involved are entirely dependent based on the location of the planned level of colon or rectal transection and were described in an earlier section. For these cases, a two-team approach with an abdominal and transanal surgeon working together during the transanal portion of the case is needed.

For hybrid taTME procedures, both a one- and two-team approach have been described to complete these operations. Regardless of the approach, procedures are performed in lithotomy position. In the one-team approach, the transanal and transabdominal portions of the operation are performed by a single team in succession. In a two-team approach, the transabdominal and transanal portions of the operation are performed simultaneously, which can reduce the operative time by allowing the abdominal team to assist with tissue retraction and dissection, and potentially reducing the risk of injury by providing a dual perspective of pelvic structures, namely, from above and below.

The operative techniques used for the operation are dependent on the exact procedure performed (completion proctectomy or APR versus LAR), indication for the operation (IBD versus rectal cancer), and the location of the pathology with respect to the anal sphincter complex.

Transanal NOTES completion proctectomy and APR

If performed using a hybrid approach, abdominal access is obtained with laparoscopic or robotic ligation of the inferior mesenteric vessels, splenic flexure takedown if needed, and left colon and rectosigmoid mobilization with or initiating of the TME from above. The perineal proctectomy

is initiated in an open fashion and carried out along the intersphincteric plane for benign disease or remains extrasphincteric in cases of advanced cancers involving the anal sphincters. Transanal dissection is extended superiorly, and the perineal muscle is divided; once the puborectalis is visualized posteriorly and the retroprostatic or rectovaginal plane is visualized, the rectal stump is closed with sutures to eliminate fecal and tumor cell spillage, and the transanal endoscopic platform is inserted. CO₂ is insufflated to 10–15 mmHg through the platform, and rectal and mesorectal dissection is extended superiorly until the rectum and mesorectum have been completely mobilized endoscopically, and the peritoneal cavity is entered with assistance from the abdominal team. The rectosigmoid specimen is transected laparoscopically and exteriorized transanally followed by perineal wound closure.

Transanal NOTES LAR

Whether performed with a one- or two-team approach, the steps of transanal dissection are dependent on the exact location of the rectal cancer relative to the dentate line and anorectal ring, as it will affect whether or not ISR is required. In a hybrid case, abdominal access and dissection proceed as previously described. Following confirmation of the exact location of the tumor by digital rectal exam, anoscopy, and/or proctoscopy, a decision is made with respect to the exact level of distal rectal transection needed to ensure a negative distal margin.

For tumors that are greater than 2 cm above the dentate line, the first step of the procedure consists of endoscopic occlusion of the rectum with a pursestring suture 0.5–1 cm below the tumor in order to avoid distention of the proximal colon with CO₂ as well as minimize fecal and tumor spillage. If the tumor is low, that is, ≤ 6 cm from the anal verge, the pursestring may be placed in an open transanal fashion, assuming adequate exposure of the tumor is achieved with the Lonestar or anoscope. After occluding the rectum with a pursestring suture below the tumor, the transanal endoscopic platform is inserted and CO₂ insufflated. Full-thickness rectal and mesorectal dissection is initiated and extended circumferentially using cautery. Posterior mesorectal dissection is carried out along the avascular plane between the mesorectal fascia and the sacrum, while anterior dissection is carried between the rectovaginal or retroprostatic fascia. Laterally, care must be taken to avoid damage to the pelvic plexus, and during anterolateral dissection of the rectum and mesorectum, care must be taken to avoid injury to the neurovascular bundles. Anterior dissection is carried out superiorly until the peritoneal reflection is reached as described earlier. Peritoneal entry is usually performed transanally and under laparoscopic visualization from above, and posteriorly, transanal dissection can usually be extended toward S1–S2 levels. The remainder of the posterior and lateral dissection is completed using a combined abdominal and transanal approach.

For tumors located less than 2 cm from the dentate line, ISR, either partial or complete, is performed first in order to achieve negative distal resection margins. ISR is performed first through a Lonestar retractor and monopolar cautery, which is extended cephalad until the puborectalis and bottom of the mesorectum are identified posteriorly, and the rectovaginal or retroprostatic plane is visualized anteriorly. The anorectal stump is then closed with a pursestring suture as described earlier followed by completion of the taTME through the transanal endoscopic platform. Following specimen extraction, hand-sewn coloanal anastomosis is performed using either end-end, side-end, coloanal J pouch, or transverse coloplasty with a protective ileostomy.

Following complete mobilization of the TME specimen, the colon is either exteriorized transanally or through an abdominal incision. An abdominal extraction incision can usually be avoided in the majority of the patients except when the specimen is deemed too bulky to permit safe transanal extraction, or when excessive tension on the marginal artery blood supply threatens perfusion of the coloanal anastomosis. Following transection of the specimen, stapled colorectal anastomosis is performed. A double pursestring stapled anastomosis technique is typically used, with either end-end, side-end, with a coloanal J pouch, or transverse coloplasty, depending on the surgeon's preference. A full-thickness pursestring suture is first placed on the distal open rectal stump either directly transanally with exposure provided with a Lonestar retractor, or endoscopically through the transanal platform if the rectal stump is higher. In the latter case, a small drain is placed on the anvil located in the proximal colon and is pulled through the distal rectal pursestring that is tied around it. The other side of the drain is connected to the spike on the EEA stapler and is used to guide the EEA stapler into the correct position through the distal pursestring. Under laparoscopic visualization, the proximal colon is pulled back by the abdominal team, which guides the spike on the stapler through the rectal stump in preparation for stapled anastomosis.⁴¹

Transanal NOTES restorative proctocolectomy

In patients with ulcerative colitis or FAP where transanal restorative proctocolectomy with ileal pouch to anal anastomosis (IPAA) is planned, circumferential rectal mucosectomy is performed at the start of transanal procedure starting at the level of the dentate line, typically using the Lonestar retractor. Following placement of the pursestring suture, the transanal endoscopic platform is then inserted, the rectum distended with CO₂, and the rectum is transected full-thickness just above the anorectal ring with circumferential rectal dissection along the mesorectal plane.⁴² Alternatively, a pursestring suture is placed 3 cm above the dentate line followed by circumferential full-thickness incision of the rectal wall endoscopically and circumferential rectal dissection along the mesorectal plane. Following

specimen extraction, IPAA is then performed using a single stapled technique or using a handsewn approach.³⁸

Limitations

Among the 13 largest taTME case series published to date, the conversion rate was 3%, and intraoperative complication occurred in 21 patients (3.1%), including significant intraoperative bleeding in eight patients, three perforations, four urethral injuries, one prostatic injury, one ureteral injury, one vaginal wall injury, one air embolism, and one injury to the iliac vessels. Intraoperative complications tend to occur relatively early in the learning curve. The use of a hybrid procedure (laparoscopic assisted) may potentially lower the risks of intraoperative complications at least until the operating surgeon has mastered the technique. The overall mortality rate was less than 1%, and the rate of postoperative morbidity was 30% across these series (Table 28.4). Some studies reported delayed postoperative complications (more than 30 days following surgery), which included anastomotic stricture, delayed pelvic sepsis, high ileostomy output, and sexual dysfunction (Table 28.4). While the published perioperative morbidity rates associated with taTME are comparable to historical rates following open and laparoscopic TME, long-term oncologic and functional outcomes, such as defecatory, urinary, and sexual dysfunction, are largely unknown and need to be investigated in larger long-term trials.

Urethral injury is a rare complication when performing laparoscopic and open TME even during a challenging APR or a recurrent case. The estimated incidence is 1.5%–2%.^{45,46} Thus far, four cases of urethral injuries during taTME have been reported in three series.^{38,47,49} Fifty percent of reported urethral injuries occurred in the Rouanet study, which was not entirely surprising given the selection of high-risk patients, including males' very low, bulky, and mostly anterior tumors.⁴⁷ The authors pointed out that the two urethral injuries occurred early in their learning curve and during dissection of bulky anterior tumors, one of which had concomitant prostatic carcinoma. Based on this report and personal communications with surgeons who have had this complication, the risk of urethral injury seems to be highest early during a surgeon's learning curve, during difficult anterior dissection, and in patients with bulky anterior rectal tumors or enlarged prostates. Although a 0.7% rate of urethral injuries among the first 720 cases of taTME voluntarily entered into the LOREC international taTME registry, was reported by Penna et al.,²⁵ it is suspected that the incidence of this injury may be grossly underreported. Risk factors for these injuries include very low rectal tumors in males when partial or complete ISR is needed, bulky and anterior tumors, a large and bulky prostate,^{47,50} previous radiation, and prior prostatectomy. Furthermore, it appears that this injury is more likely to occur early in the adopter's learning curve, when the operator is insufficiently trained in and familiar with the bottoms-up and deep perineal

anatomy. These reports again emphasize the critical importance of adequate procedural training in taTME, proctoring during operators' early experience, and participation in a taTME registry.

CONCLUSIONS

Pure and hybrid transvaginal and transanal NOTES techniques during laparoscopic or robotic colorectal resections offer the advantage of further reducing the morbidity and incisional pain associated with minimally invasive surgery by eliminating the need for an abdominal extraction site. Despite the fact that transvaginal and transanal assistance and specimen extraction during colectomy have been demonstrated to be feasible, safe, with potential yet limited clinical benefits over standard multiport or colectomy, adoption has plateaued. This trend may result from concerns about a longer learning curve and operating time, and from the lack of public interest or demand for transvaginal NOTES in general. The introduction of transanal endoscopic NOTES proctectomy (taTME) continues to revolutionize the surgical management of low and mid-rectal cancer. Beyond the benefits of transanal specimen extraction, this approach has enabled the safe completion of TME for rectal cancer in the most adverse of cases, namely, in the obese male with tumors ≤ 6 cm from the anal verge. In addition, based on the preliminary data from registries and publications to date, taTME might enable surgeons to reduce conversion rates to open surgery, improve the quality of TME specimens, and increase the rate of sphincter-preserving LAR over APR. However, these operations are technically demanding and require prerequisite expertise and training, with a clear learning curve demonstrated in human cadaver studies. Future improvements in surgical platforms including robotic technologies for NOTES may soon enable even wider adoption, and move this field one step closer to the holy grail of pure transanal NOTES colorectal surgery.

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Preparation for minimally invasive surgery



Dana Schutz, *Surgery*, 2004. Oil on canvas, 75 × 91 inches. Nerman Museum of Contemporary Art, Overland Park, KS.
(Courtesy of the artist and Petzel, New York.)

How does one paint what can't be seen? Rather than depicting what a surgery actually looks like from the perspective of an observer or a member of the surgical team, this image by painter Dana Schutz communicates how it feels for the patient to undergo a procedure. This woman's fractured

body is being operated on by several different doctors at once: one inserts an instrument into her open skull, another works on her abdomen, while a third sutures her twisted leg. Her limbs seem to melt into the checkerboard table and a distraught expression reveals her emotional experience.

The patient is, at the same time, an object of study and an individual confronted with the fear of medical intervention. While the doctors observe her body attentively, her empty gaze highlights their lack of connection. The vegetation that surrounds the table further emphasizes her disconnectedness from both the natural and social worlds and provides an uncanny feeling to the scene. She is both subject and object, human and non-human.

Schutz has garnered much acclaim for portraying everyday activities and events with a distorted sense of humor, what one critic called her own brand of “merry macabre.” For the artist, these scenes are “artifacts” of the various

situations that she imagines. Here she has envisioned an all-female operating room in which the doctors operate without the use of technological assistance and surrounded by natural light and environment. The layers of bright, non-natural colors, and mask-like faces exaggerate the emotional content, and the multiple viewpoints allow viewers to see the patient from above and the team of doctors from the side simultaneously.

Quotes from Mei Chin, “Dana Schutz by Mei Chin,” Bomb, no. 95 (September 2006), <https://bombmagazine.org/articles/dana-schutz/>.

Telementoring in minimally invasive surgery

IAN CHOY AND ALLAN OKRAINEC

INTRODUCTION

Telementoring in surgery was first established in the 1960s when surgeons in Texas transmitted a live video of an aortic valve replacement to Geneva.^{1,2} However, these early efforts were plagued by the technological limitations of the time. It was not until the 1990s when advances in both surgical and telecommunication technology made telementoring both practical and feasible. Today, surgeons have adapted telementoring to a wide array of applications including teleproctoring, telesimulation, and telesurgery.

Research studies evaluating telementoring have evolved significantly since the resurgence of telementoring in the 1990s.³ Early studies focused on the feasibility and efficacy of telementoring in surgery.^{4,5} Issues such as hardware logistics of the telesurgery systems were examined. More recently, the literature has started delving deeper into the utility of this technology, examining the clinical and educational outcomes of telementoring in surgery.³

With health-care systems worldwide tightening budgets and rethinking how care is delivered, the potential benefits of telementoring in terms of education, quality improvement, and patient access have led to further interest in this technology and given a sense of urgency to its implementation.⁶ Studies now not only examine the viability of telementoring, but are also looking into novel applications in surgery and surgical education.

This chapter explores the current state of telementoring in surgery. Using a thematic approach, the literature was reviewed and grouped into three broad applications: (1) telementoring in surgical education, (2) the use of telementoring in remote and resource-restricted contexts, and (3) utilizing telementoring to facilitate professional collaboration between centers of excellence. The obstacles to widespread adoption and opportunities for future implementation are presented.

WHAT IS TELEMENTORING?

Telementoring in surgery is when an expert surgeon remotely assists, directs, or assesses another surgeon within a simulated or real clinical context.⁷ The Society of American Gastrointestinal and Endoscopic Surgeons recently defined telementoring as a relationship, facilitated by telecommunication technology, in which an expert provides guidance to a less experienced learner from a remote location.⁸ Within real clinical scenarios, telementoring programs can involve multiple phases of care including the initial consultation, surgery, perioperative care, and follow-up. Furthermore, with the advent of laparoscopic and robotic surgery, telementoring has become even more applicable to these clinical scenarios. By leveraging their natural existing video interface, expert surgeons can mentor, guide, and assess an operation on a patient through telementoring.

As interest, resources, and development in telementoring have progressed, so have the applications for which telementoring can be utilized. A whole host of new definitions associated with telementoring have evolved. Teleproctoring is the remote examination, assessment, or credentialing over videoconferencing. Telesurgery is robotic-assisted surgery whereby a surgeon operates at a distance on a patient who is at a distance. Finally, telesimulation is when an expert remotely mentors a novice surgeon or trainee in a simulated task ([Table 29.1](#)).

TELEMENTORING IN SURGICAL EDUCATION

Surgical training is unique among the various medical specialties as it relies heavily on experiential skills that are gained through the practice and performance of surgical procedures. For well over a century, surgical training has been predominantly grounded in a traditional mentorship/

Table 29.1 Summary of key terminology

Telemedicine	The practice of medicine and/or teaching of the medical art, without direct physical physician-patient or physician-student interaction, via an interactive audio-video communication system employing tele-electronic devices ^{8,9}
Telementoring	A relationship, facilitated by telecommunication technology, in which an expert provides guidance to a less-experienced learner from a remote location ⁸
Teleproctoring	Live proctoring of examination, assessment, or credentialing over video conference ¹⁰
Telesurgery	Robotic-assisted surgery, whereby the surgeon operates remotely on a patient who is in a distant location ¹¹
Telesimulation	A novice surgeon does simulated tasks with the remote assistance of an expert surgeon ¹²

apprentice model, whereby the expert surgeon engages in close long-term relationships with students to teach novice surgeons through observation and “trial and error.”¹³ Constraints in the medical education system such as patient safety concerns, restricted work hours, and expanded skill requirements have led educators to look at alternatives to this traditional apprenticeship model.

Telementoring has been embraced as an important educational tool, providing surgical trainees improved access to experts and mentors and facilitating engagement with surgical techniques that trainees may not otherwise have had exposure to.¹⁴ This has become especially important with the increased pace of technological advancement in surgery resulting in large variations in resident exposure to advanced laparoscopic procedures between surgical training programs.⁵

Telementoring also plays an important role in the evaluation of surgical skills. It provides mentors with more opportunities for continuous and longitudinal observations of trainees. Furthermore, in situations with more advanced trainees, telementoring creates a beneficial distance between the trainee and mentor. This has been shown to improve both the competence and confidence of trainees, facilitating their ability to operate independently.¹⁴

There remains, however, significant work to be done to elaborate on specific educational outcomes and applications for telementoring. Much of the early telementoring studies have been survey based, demonstrating that surgeons positively view telementoring as an educational activity to acquire new skills and knowledge.¹ More recently, specific outcome measures have been used to demonstrate the reliability of telesimulation as well as trying to determine the baseline infrastructure requirements for these activities.¹⁵ Future studies need to build on these findings and adapt telementoring to more high-fidelity scenarios.

One such advancement in surgical education is the incorporation of simulation into telementoring programs. Simulation has become an important educational tool for training for many of the same reasons that have driven interest in telementoring. As an alternative to the traditional apprenticeship model of training, simulation technologies provide greater opportunity for trainees to master skills in low-stress environments while enabling increased feedback during practice and testing.^{9,16} Therefore, simulation is an

ideal tool for teaching novice learners new techniques that they have never been exposed to.

Telesimulation offers a unique application within education for telementoring programs. Trainees and mentors can work together remotely on box simulators or with even more complex software simulators.^{17,18} Trainees can then practice and learn new techniques before applying them on patients. This has been particularly useful when applied to highly specific and technically challenging tasks, with much of the more recent research focused on trying to find the best way to incorporate these tasks into the overall surgical curriculum.¹⁶ Use of this technology also has significant potential for teleproctoring high-stakes examinations such as the Fundamentals of Laparoscopic Surgery (FLS), where remote assessment of laparoscopic skills has been shown to be as reliable as in-person assessment. This approach has the potential to increase FLS certification rates around the world in a cost-effective manner.¹⁹

The plethora of mobile technology offers yet another opportunity to expand and incorporate telementoring further within surgical education. The ubiquity of Internet-enabled cell phones provides a mobile interface that can be used in many different educational scenarios. This has the potential to make telementoring accessible to more trainees at a lower cost.¹ Technologies such as Google Glass and augmented reality may help to expand telementoring to open procedures. Much of the current research on telementoring has been limited to laparoscopic procedures due to the fact that this surgical environment already incorporates an electronic interface. Augmented reality provides the necessary technology to apply telementoring to a wider array of open procedures and techniques. The major limitation with the current technology is the video quality of the live streaming feature, which will certainly improve with time.^{9,20,21}

One potential concern regarding the application of telementoring is that the technology may itself be viewed as a new educational paradigm. With curriculum development in the spotlight of medical education literature, it is important to recognize that telementoring is simply another tool to facilitate surgical training, and that it must still be used within the context of established educational theory.

TELEMENTORING AND TELESURGERY IN REMOTE AND RESOURCE-RESTRICTED CONTEXTS

The second application of telementoring that has been widely described is its use in remote settings. Remote telementoring connects two or more hospitals over large distances for the purposes of education, collaboration, and remote surgery. Remote telementoring often has an international focus, particularly in resource-restricted contexts that are physically isolated. Telesurgery has developed out of telementoring programs in these remote contexts. Telesurgery differs from telementoring in that it allows expert surgeons to take control of the procedure themselves when necessary.

In addition to a focus on continuing education opportunities for surgeons in these remote settings, telementoring has been used to try and improve standard of care, increase access to subspecialty services, reduce patient transfer rates, and provide better emergency care. In many areas there is a dire shortage of subspecialist surgeons.²² Telementoring is one way to address this shortage and provide both expertise and education where human resources are limited. Transferring patients not only comes at a large financial cost but also disconnects patients with the social networks that can be paramount for their recovery.²³ Finally, improved access to emergency care can prevent morbidity and mortality related to accidents.²³

One of the largest studies on telementoring was from McMaster University where a telementoring and remote telepresence program was established with a community hospital in northern Ontario and Quebec.^{22,23} Over 9 years, the Centre for Minimal Access Surgery, based at McMaster University and St Joseph's Hospital, offered over 100 telementoring sessions to several surgeons in these remote communities. Starting in 2003, 22 telerobotic-assisted surgeries were also completed. From these different phases of their telementoring program, the group wrote from a unique perspective of lessons learned when building a telementoring program. They found that patient acceptance of the telementoring and telerobotic surgery was paramount to the success of the program. Also, having an understanding of the time delay that occurred during telecommunication was important to the success of telementoring sessions.

Furthermore, when these programs cross national and cultural boundaries they can face a host of challenges and barriers that are often discussed within the international development community. One qualitative analysis of the development of novel surgical programs in a resource-restricted setting stressed the importance of developing a thorough understanding of the local surgical culture and context. A needs assessment of the local community is required in order to make informed decisions about how to best integrate new technology with the existing physical and social infrastructure.²⁴

The major limitations to this work are licensing and regulation differences locally, regionally, and internationally. These can represent a large barrier to developing and implementing telementoring programs.¹⁶ Furthermore, developing ethical guidelines and protocols and addressing legal challenges to protect both the patients and participating doctors is an important first step in developing a program. Access to communications technology required for telementoring is another obstacle to establishing telementoring programs in remote contexts. This issue is particularly problematic in developing countries where telementoring has some of the greatest potential to improve educational opportunities and clinical practice. Finally, there are concerns of privacy, security, and reliability of telecommunication networks, which may limit the reach of telementoring programs.²⁶ This is particularly important in cases where patients are involved, such as in telesurgery, where a recent study demonstrated that certain surgical robots are susceptible to cyberattack.²⁷

TELEMENTORING AND PROFESSIONAL COLLABORATION

Finally, telementoring holds great potential in fostering collaboration between academic institutions. Surgical practice is closely connected to the mentors and locations where a surgeon trains. Consequently, surgical techniques and management of patients can vary between different locations.²⁸ Historically, there are established ways of sharing and communicating innovation in surgery including conferences, scientific journals, visiting professorships, and rotation of surgical trainees between institutions. Recently, with the emphasis on evidence-based medicine, there is a growing need to compare, develop standards of practice, and engage with professionals.²⁹ However, these more traditional modes of diffusion of innovation can be slow and cumbersome.

Telementoring can be established as an alternative knowledge-sharing activity, whereby institutions can share cases and management strategies in real time. Institutional collaboration is defined as the interorganizational relationship involving shared authority and responsibility over planning, implementation, and evaluation of a project.²⁵ Telementoring applications to date have focused on interactions between academic and community surgeons and experts with novices. Telementoring could potentially also be used for surgeons and their surgical teams at large academic institutions to connect and collaborate with each other. There is benefit to connecting experts together in different locations to share how cases are done in their respective contexts. The telementoring of surgical cases provides an opportunity for multidisciplinary teams to discuss aspects of pre- and postsurgical care and incorporate collaboration in the operating room for particularly challenging cases.

CONCLUSION

With the ongoing development and increasing ubiquity of mobile telecommunication devices, it is inevitable that these tools will be incorporated into our educational and clinical environment. Telementoring is the result of this merger and offers great potential for helping surgeons learn and maintain their skills. It is important for the surgical community to continue to be engaged in the development and adoption of telementoring technologies, in order to address their limitations, and ensure that the innovation remains the path, and not the destination.

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Objective metrics in the simulation of minimally invasive surgery

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INTRODUCTION

Minimally invasive surgery has been a major driver in the development of simulation platforms in surgery. Simulation-based training provides a standardized and more controlled environment in which to acquire and assess surgical competence. We have a responsibility, however, to demonstrate the value of the incorporation of simulation-based curricula into our already time-starved and resource-limited residency programs. Metrics are, therefore, intrinsically linked to the use of simulation whether for training or assessment. Furthermore, as we find ourselves in the midst of education reform toward a competency-based model, metrics have an increasingly important role in helping us to provide objective evidence that learners have achieved milestones and have demonstrated competence in a given area. If simulation is going to be used to assess the practicing surgeon, or for the purposes of privileging, the metrics must meet the standards for high-stakes evaluations, and the test must have validity evidence from multiple sources. This chapter reviews the existing types of metrics used in the simulation of minimally invasive surgery including time and accuracy, motion analysis, measures of surgeon physiology, and assessment rubrics, and briefly highlights some of their strengths and weaknesses.

PURPOSE OF METRICS IN SIMULATION

As mentioned, metrics can have both formative and summative roles in simulation training. Scores from metrics provide information such as proficiency goals and decisions based on pass/fail benchmarks, track individuals' progress

for both trainees and instructors, and possibly predict performance in the clinical setting.^{1,2} Metrics and their scores must be tightly linked with learning objectives and content in simulation training, and scores should discriminate between individuals who perform at different levels that would be considered clinically relevant. In order to be useful and provide trustworthy information, metrics should measure what they are supposed to measure.

THE IMPORTANCE OF VALIDITY EVIDENCE

Validity is a fundamental component of any metric and refers to the degree to which evidence supports the intended interpretation of scores for the proposed use of metrics.^{3,4} The systematic collection of validity evidence for given metrics includes the following five sources of validity: content, response process, internal structure, relationship to other variables, and consequence. The scores from metrics used in simulation environments can be interpreted as a representation of the intended construct. Evidence should be obtained from various sources to support a given interpretation. The term *reliability* denotes the consistency and reproducibility of scores. Measurement error also needs to be accounted for in determining the validity of a given form of assessment. Errors could potentially occur due to various factors, including raters, occasions, and systems. It is important to make an effort to recognize and minimize these errors for intended use. Metrics should be selected according to the interpretation and intended use of scores. In this chapter, we overview the different approaches currently available for assessing performance in simulation environments, and we highlight the strengths and weaknesses of these approaches ([Table 30.1](#)).

Table 30.1 Features of metrics in simulation

	Strength	Limitations
Time and accuracy	Practical—ease of implementation Data supporting validity evidence	Potential human error, not useful for formative feedback, may encourage habits that are not clinically relevant
Motion-based metrics	Computerized techniques (consistent measures across trainees)	Costly; maintenance issues (instruments and software); complexities of data interpretations—not always clear what is meaningful; resolution and accuracy must be very high
Physiological measures	Incremental value; computerized techniques	Costly; interpretation of some measurements results could be difficult; not clearly relevant, validity data are mixed
Performance rubrics	Could provide meaningful feedback on performance; integrates expertise of the rater	May be affected by rater bias and other potential sources of error; resource intensive due to the need of a rater

REVIEW OF METRICS IN THE SIMULATION OF MINIMALLY INVASIVE SURGERY

Time and accuracy

Many of the simulators to teach and assess minimally invasive surgery use deconstructed tasks that model certain skills and behaviors that are relevant to the field. Time (time to complete the tasks) and accuracy (precision or error) have been widely used for assessment of trainees in a wide range of minimally invasive simulation-based training.⁵ Interpreting the meaning of such results is straightforward. It is also easy to implement without sophisticated technologies. This metric is currently used as part of the assessment of the technical skills part of Fundamentals of Laparoscopic Surgery (FLS) that consists of five laparoscopic tasks performed in a video box trainer.⁶ Many studies have provided evidence for the validity and reliability of time and accuracy as measures of laparoscopic skill using these tasks.^{7,8} Scores in the simulator have also been shown to correlate with and predict clinical performance in the operating room.⁹

Time is extremely practical, reliable, and easy to measure. The determination of accuracy (error) should be associated with the clinical importance and weighted to optimize measurement precision in order to discriminate between levels of performance. For instance, when a trainee performs a laparoscopic intracorporeal knot, if the knot is not secure, this would be considered unacceptable in the operating room, regardless of how fast it could be done. Therefore, accuracy needs to take these clinically fundamental consequences into account, as errors and penalties should be assigned as part of the assessment. These errors, in order to be measured, must be objectively observable. Although time and accuracy metrics are very acceptable assessments, they have a limited ability to assess the quality and ultimate safety of performance. In addition, these metrics, although objective, provide little if any meaningful information that trainees can use for improvement of their performance or as formative feedback. Time components may also encourage trainees to focus on faster performance at the expense of developing potentially unsafe habits. A proficiency-based simulation training program based on time and errors

should be supplemented with qualitative and specific feedback from expert coaches such that trainees can learn from their mistakes and adopt practices that are clinically relevant and transferable.

Motion-based metrics

Motion analysis is a computer-based technique that has been used in many different simulated settings to measure various aspects of the movements surgeons make during the performance of surgical tasks or skills. It requires a system for tracking and recording instrument motion (orientation and position) as well as a specialized program for analysis of the data.¹⁰ Although the tracking system is usually separate from the simulation system/box except for in most virtual reality simulators where the system is preinstalled, many of the existing systems might eventually be adapted for *in vivo* use.

Most tracking systems consist of a signal source, a sensor, and a system, which processes the signals received. Current technologies use mechanical, optical, electromagnetic or acoustic signals for motion tracking. Motion tracking can be done by taking measurements from instrument tips, tracking hand-held objects, or detecting body motion.¹¹ For any motion analysis system, resolution and accuracy are thought to be very important, since the precision of the instrument motion measurement relies on those two components of the system.¹²

Currently, apart from time, which is usually measured, most motion tracking systems are based on some sort of algorithm that takes into account path length, length of the curve, number of movements, distance traveled, rotation and orientation, smoothness and acceleration, just to name a few.¹³ The real challenge is in trying to determine the metrics that have clinical relevance and that correlate with clinical performance. These measures are time-dependent, three-dimensional representations of the instrument tip motion and the instrument rotation around its axis. Most systems use multiple measures, and choosing the right combination depends on the task that is being performed. Even though motion-based parameters

are very objective metrics to discriminate training levels (comparison between different experience levels), work is also needed to understand how to interpret the data, and how to use it to provide relevant feedback to trainees so that it can be used for skill improvement. It is challenging to convert these parameters into meaningful data beyond discrimination. Adding data on the external posture of the surgeon is currently being integrated into such parameters in order to better understand expert performance.

Measures of surgeon physiology

Physiological monitors allow for the measurement of surgeon reactions as they are asked to perform in a variety of simulated situations. Included are devices that measure eye tracking and monitors that collect data about various physiologic responses to stress. Eye tracking systems are purported to measure aspects of cognition (a “window into the brain” and skill level while completing a task). Monitors that measure surgeon stress have been gaining popularity since excessive stress could impair technical skills as well as memory, vigilance, and other cognitive abilities. It is also known that stress can affect a surgeon’s communication and decision-making skills. There are many markers that could be used to assess and quantify stress levels, including heart rate, skin conductance level, and salivary cortisol levels. The effect that stress has on the sympathetic nervous system can therefore be measured using these markers. These parameters are mostly being used to assess performance in the research setting.

One of the more established physiologic parameters used to measure laparoscopic performance in the simulated environment is eye tracking.¹⁴ It involves documenting eye movements through stationary cameras or cameras integrated into eyeglasses. These will allow the tracking of pupil position, which maps the focus of attention of the subject (gaze). Other measures also include fixation frequency, dwell time (perceived stimulus), and pupil dilation (associated with effort in cognitive processing). Differences in the results between subjects could be used as a way to differentiate varying levels of skill. The most common eye tracking assessments used are gaze and attention to differentiate expertise levels; experts seem to have greater fixation to the relevant anatomic targets compared to novices. Some have used eye tracking in surgical training to improve subject performance. Subjects were trained to focus on critical points or expert eye-tracked benchmarks and demonstrated improved performance after practice. Overall, focused attention is key for expert performance and could be described in two ways. First, fixation rates tend to be higher for experts because they know what they are looking for and can identify known patterns much more quickly and easily than novices. Second, the cognitive activity required of experts tends to be lower in routine procedures since nonexperts tend to have a higher degree of cognitive workload because they are not as familiar with the procedure and its steps. At

the end, eye tracking systems hold a potential for usage as an assessment and an educational tool in simulation, since trainees could be assessed in comparison to benchmarks established by expert performances. Trainees could also be guided to focus their attention “more expertly” depending on the task, which might help them to develop the expertise needed more efficiently. In order to fully understand the system’s potential, further research is also needed to test its value as a feedback tool.

Heart rate, skin conductance, and cortisol levels are other markers, and changes in their activity and release depend on stress levels.¹⁵ For instance, for skin resistance, depending on where the electrodes are placed, the difference in resistance serves as a signal for sweat gland activation, which could result from an increase in stress levels in response to a given set of conditions. Even though these could be good ways to quantify a surgeon’s stress, it would be difficult to use them as assessments or for educational purposes (formative feedback to trainees) since stress levels vary greatly from surgeon to surgeon, and they have not been consistently shown to correlate with experience level.

OTHER RUBRICS USED TO MEASURE PERFORMANCE

In general, the metrics mentioned above provide relatively limited information on the quality and transferability of simulator performance. Use of performance assessment metrics such as global rating tools, checklists, and error rating tools can complement the other metrics and perhaps provide more meaningful feedback. There are three types of performance assessment rubrics commonly used to assess minimally invasive surgical performance in the simulated setting: generic, task-specific, or a combination of generic and task-specific (hybrid) types.¹⁶ In general, generic rubrics are flexible and suitable to assess trainee performance across different, but related, simulated tasks, whereas task-specific rubrics obtain more specific information but are less flexible. Hybrid rubrics have currently been attracting more attention because they tend to provide complementary and more comprehensive information. Exploring and identifying domains that better reflect quality of performance on particular tasks and quantifying such domains are key for successful integration. One of the concerns about implementation of these rubrics is score reproducibility across raters. These metrics depend on humans to complete them, and this can have both advantages and disadvantages. The advantage is that the rater (most often an expert) can call on his or her expertise and quickly integrate a lot of information when completing the assessment, such as equipment issues, case difficulty and patient factors (if in the clinical environment), and other situational parameters that might impact performance. The disadvantage is the potential for bias, measurement error, and the practical constraints of needing to schedule busy experts to assess performance, just to name a few.

CONCLUSION

Currently, time and accuracy, motion-based metrics, physiological parameters, and performance rubrics are available for assessing laparoscopic surgical performance in the simulation setting. The type of simulation, intended use, and interpretation of scores from any given situation should be considered before selecting and implementing them. The amount and sources of validity evidence needed depend on the intended use and interpretation of scores and should be considered especially when using any type of simulation-based test to make a clinical decision about competence or privileging. Simulation may have a very important role to play in the era of competency-based surgical education, and it is well-suited to the field of minimally invasive surgery. The value of any type of simulation-based tool, however, will depend on the rigor with which it has been shown to teach what it is supposed to or measure what it intends to.

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Virtual reality simulation in minimally invasive surgery

SUVRANU DE

INTRODUCTION

With its many advantages of minimal postoperative pain, few postoperative adhesions, minimized blood loss, low risk of surgical complications, short hospital stay, and early return to normal activities, minimally invasive surgery (MIS) has revolutionized general surgery. However, performing MIS is a complex task involving independent visual and manual skills, and skills learned during open surgery are not easily transferable to laparoscopic procedures.¹ A laparoscopic surgeon needs to learn to operate with a two-dimensional view of a three-dimensional situation. In addition, he or she has to do without the all-important tactile sensation, significantly hampering depth perception. Laparoscopic manipulations require precise eye-hand coordination, with long and slender instruments. Retraction is quite unlike that which surgeons customarily take for granted. Even simple knot tying has to be learned anew, as an intracorporeal laparoscopic knot is different from the traditional two-handed knot. All of these factors predispose to an increased probability of complications (e.g., the relatively high incidence of biliary injuries reported in the early years of laparoscopic cholecystectomy).² Hence, the importance of training in MIS cannot be overstated.

While the need for training is recognized, developing an effective training program is not straightforward. Such a program should provide due consideration to the types of skills to be learned, metrics of measurement, benchmarks for learners to achieve, and modalities of feedback and reflection.³ The goal should be to build toward expertise in a stepwise manner, in which basic skills are acquired first and are eventually combined into complete tasks performed in realistic settings. This calls for multiple training modalities ranging from simple part task trainers to high-fidelity

simulators. However, learning technical skills is just one aspect of surgical expertise. After mastering technical skills, surgeons must combine them into complex tasks and procedures. In addition, they must learn to work collaboratively in a team environment under stressful conditions with enough spare attention to multitask.

Traditionally, trainees have acquired surgical skills through an apprenticeship model, in which they observe senior surgeons and perform under their guidance. However, recently the Halstedian model has been turned on its head for multiple reasons, not the least of which is increased concerns regarding patient safety, reduction in work hours, less contact with patients, and reduced procedural experience during residency. The modern training paradigm has thus evolved to include a variety of simulators and models such as live animals, cadavers, inanimate video trainers (VTs), human patient simulators (HPSs), virtual reality (VR) computer-based simulators, and hybrid simulators. Although human cadavers most closely approximate reality, their cost and limited availability, as well as the poor compliance of cadaveric tissue, limit their use. The use of live animals is also problematic because of ethical concerns, high costs, and the need for specialized facilities. A VR-based simulator, with both visual and haptic (touch) interfaces, affords the best simulation environment for deliberate practice for critical scenarios; it overcomes these limitations. Unlike training toolboxes or video trainers, VR-based simulators provide unlimited training scenarios without the risk of adverse consequence to patients, expose trainees to rare adverse events, allow customization based on individual needs, and provide detailed and objective feedback in real time, independent of a proctor.

Price point and lack of adequate realism, particularly in force feedback, have been implicated in the lack of

widespread use of VR-based simulators. There are, however, three major reasons that we believe that in the future, VR simulators, particularly those that allow full immersion, will eclipse all other surgical training modalities. First, VR simulations will become increasingly realistic, riding on the exponential growth in computing power. The incredible power of this phenomenon is apparent in the way that computer-aided design has revolutionized engineering, where digital design is a norm in industries as complex as aviation and automotive. Second, VR provides the only means of generating and presenting complexities in a controlled manner with the ability to measure performance in real time and provide objective feedback. Finally, based on Rasmussen's skill-, rule-, and knowledge- (SRK) based framework of human behavior,⁴ we argue (in the next section) that VR is the *only* comprehensive training modality, including training of technical and nontechnical skills. Skill-based behavior and some rule-based behavior may be taught using box trainers, *ex vivo* or *in vivo* animal models. Immersive VR that includes high-fidelity visual as well as other sensory feedback in a seamless fashion will provide the only means of achieving true surgical expertise by addressing all three levels of human behavior.

While there are various companies developing VR-based simulators, our intent is not to discuss specific products and systems in this chapter. Instead, in the section "Rasmussen's SRK Framework and VR Simulation," we provide a theoretical argument that fully immersive virtual environments are the only ones that can provide training of SRK-based behavior, including some examples. In section "VR Simulation Technology," we discuss some challenges to current VR simulation technology. The chapter ends with concluding remarks.

RASMUSSEN'S SRK FRAMEWORK AND VR SIMULATION

Rasmussen⁴ provides a framework for describing human behaviors as skill, rule, or knowledge based, which can be used as a reference when designing surgical training curricula. Skill-based behavior refers to automated actions that can occur with minimal attentional resources. For well-practiced and routine actions, skill-based behavior is governed by patterns of activity stored in memory. Rule-based behavior requires an individual to direct conscious attention to recognizing a situation and retrieving appropriate rules from memory and applying them. Finally, in an unfamiliar situation for which there are no prespecified skills or rules, the individual must analyze the situation carefully and improvise, which constitutes knowledge-based behavior. While skill-based behavior requires the least attentional resources due to greater familiarity with the environment, knowledge-based behavior requires the highest, as the task to be performed is not familiar.

Based on Rasmussen's model, only VR-based simulators can address each of the behavior levels. Existing VR-based

simulators can support skill-based behavior by enabling basic hand-eye coordination and simple technical skills. A widely used laparoscopic surgery training system is the MIST VR,⁵ which was introduced in the 1990s as a low-cost VR trainer, and several studies have demonstrated that training with the MIST VR has been useful in overcoming visuospatial and psychomotor challenges inherent in performing laparoscopic surgery.⁶

A more recent example of a VR-based trainer for elementary surgical skills is the virtual basic laparoscopic skill trainer (VBLaST).⁷ This is the virtual counterpart of the Fundamentals of Laparoscopic Surgery (FLS) toolbox, developed by the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) that is now part of board certification in surgery. The FLS toolbox consists of a box covered by an opaque membrane through which two trocars are placed on either side of a 0° laparoscope connected to a video monitor. Inside the box, five premanufactured tasks including peg transfer, pattern cutting, ligating a loop, and suturing can be performed. Potential drawbacks of such a system include requirement of expert proctors and trainers, manual and non-real-time assessment, and constant supply of practice materials.

The VBLaST has been developed to overcome these problems, whereby tasks such as the ones available in the FLS system may be performed on the computer. It consists of computational software to simulate the FLS tasks, and a physical user interface (Figure 31.1) to connect two laparoscopic

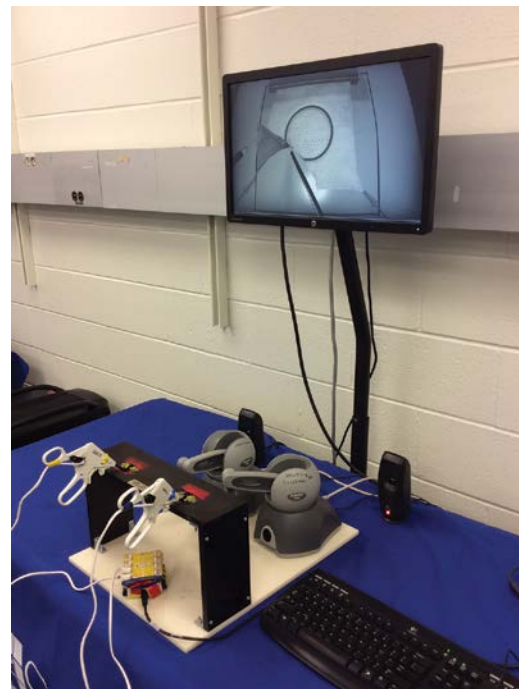


Figure 31.1 The VBLaST represents the virtual versions of the FLS tasks. Shown is the virtual pattern cutting task. Interaction with the environment is provided using laparoscopic tools attached to the Geomagic Touch haptic feedback device.

tools (the same as those used for the FLS box-trainer) to two Geomagic Touch devices (3D Systems, Rock Hill, South Carolina). These devices have 6-DOF (degree of freedom) positional sensing, 3-DOF force feedback, and a removable stylus for end-user customization. The users can hold onto the instrument handles with their hands, moving them in the “real space” while watching what they are doing inside the virtual workspace on the computer screen. The haptic devices simulate force feedback when the users interact within the virtual environment. Multiple validation studies (face, content, construct, and convergent) of the VBLaST system have been performed (e.g., see Chellali et al.⁸ and Zhang et al.⁹), establishing it as a reliable alternative to the FLS.

Beyond basic skills, virtual environments can also be used for whole-task training to help individuals learn proper sequences of steps and transitions between them (i.e., rule-based behavior). There are various procedural trainers in the market for cholecystectomy, appendectomy, bariatrics, and other laparoscopic procedures.

For developing knowledge-based behavior skills in particular, the use of training scenarios that highlight rare or unusual circumstances, or present unexpected complications, can be especially useful. For instance, operating room fire is an uncommon but devastating problem. Around 600 such fires are encountered annually. Being able to learn the conditions under which such disasters occur and being able to mitigate that is one of the objectives of the Fundamental Use of Surgical Energy (FUSE) initiative of SAGES. Operating room fire training is complicated by the strict regulations currently in place with regard to the source of open flame or smoke, enforced by the absolute majority of the hands-on surgical skill labs. Similar restrictions exist for simulated smoke sources, such as dry ice, fog machines, etc. And, when considering some of the larger-scale operating room fire event training (e.g., combustible gas explosions), a comprehensive training for surgical fire prevention in real life becomes near impossible.

The Virtual Electrosurgical Skill Trainer (VEST) is a VR-based simulator to support the FUSE curriculum. One of the modules of the VEST includes a scenario for training of operating room fire. The virtual simulator’s hardware consists of two primary components: an immersive three-dimensional display and an interaction device. The former is provided by the Oculus Rift stereoscopic head-mounted display (HMD) (<https://www.oculus.com>). The Oculus Rift HMD offers precise, low-latency positional tracking and eliminates most of the problems commonly associated with the previous-generation VR headsets by using a low persistence OLED display to drastically reduce motion blur and judder, two of the biggest contributors to simulator sickness. The interaction with the virtual environment is provided via a custom-built controller, held by the user during the simulator’s operation. The controller incorporates a 6-DOF positional tracker from Ascension Technology Corporation (<http://www.ascension-tech.com>), as well as a push-button switch, allowing the user to “touch” the virtual objects and interact with them as needed (**Figure 31.2**).



Figure 31.2 An immersive simulation environment for operating room fire has been developed and validated for VEST. The user wears a HMD system (Oculus Rift) and interacts with the objects within the operating room using a handheld pointing device.

Another example of a low-frequency high-acuity surgical event is cricothyrotomy—a procedure in which an incision is made through the skin and cricothyroid membrane to establish a patent airway for trauma patients. Only a very small fraction of trauma patients who are intubated require a surgical airway, and a resident may not encounter a single case during residency. However, it is expected to take approximately 30 cases to attain proficiency in the acute management of the unexpected difficult airway, which few residency programs can provide. A Virtual Airway Skill Trainer is being developed to enable training on this procedure in a VR setting.

VR SIMULATION TECHNOLOGY

The ultimate goal of VR simulators is to mimic reality, which is challenging to achieve. Take, for instance, the example of suturing. This apparently simple task is extremely challenging, especially to represent the proper physical response of the suture, the correct friction conditions between the tissue and the thread as it is pulled through it, the mechanics of knot tying, and maintaining the knot in place—all of these require great attention to detail.

One of the “grand challenges” listed by the U.S. National Academy of Engineering is the challenge to enhance VR. In particular, the lack of visually precise detail and the lack of realistic tactile and haptic feedback have traditionally been pointed out as areas that are in need of significant enhancement in virtual environments, but technological advancements in computational hardware, VR interfaces, and numerical algorithms are quickly improving the capability to create high-fidelity, multimodal virtual environments.

VR-based simulation environments are human-in-the-loop systems by nature. All of the entities of the virtual

environment such as visual rendering effects, tactile feedback, etc., should therefore adhere to the constraints of real-time update. This translates to a visual feedback that is a minimum of 30 Hz. The requirement for tactile feedback is much more stringent—around 700 Hz for soft contacts and close to 1000 Hz for stiff contacts. One of the main challenges of building a real-time VR environment is to be able to generate the required frame rate by performing rapid computations. This may be achieved by developing faster algorithms and more efficient hardware.

Most of the real-time VR applications relied traditionally on commodity hardware such as desktops and workstations. The computing power of the central processing units (CPUs) has grown exponentially since the mid-1980s. Researchers over the years have taken advantage of the parallel capability hardware through parallelizing the algorithms using shared memory parallelism.

The advent of graphical processing units (GPUs) as a general-purpose computing hardware architecture has boosted the performance of the applications enormously. GPUs are inherently parallel with thousands of cores enabling highly parallel processing of instructions. Present-day GPUs can reach a peak performance of up to 1600 Gflops surpassing the parallel CPU architectures. Software architectures such as CUDA and OpenCL have further popularized the GPUs as a general-purpose computing hardware platform. Many applications developed for GPUs have achieved orders of magnitude speedups.

CONCLUDING REMARKS

In this chapter we have discussed the critical role that VR technology will play in the future of surgical training to reach expertise based on Rasmussen's SRK framework. The path toward immersive VR is, however, challenging,

as substantial developments are necessary in the fields of immersive display systems and computational hardware.

However, the future of immersive VR is very bright, with significant advancements in both algorithms and hardware already under way. Deformable organ models with tens to hundreds of thousands of degrees of freedom can already be simulated at real-time rates with haptic feedback. It is expected that such simulations with tens of millions of degrees of freedom may be possible within the next decade. Immersive display systems have seen drastic price reductions. Head-mounted displays used to cost thousands to tens of thousands of dollars. Now, very high resolution immersive HMDs such as the Oculus, cost a few hundred dollars. Samsung's Gear VR and Google's Cardboard allow even less expensive options of directly using one's smartphone to generate immersive environments. In contrast, advances in haptic devices have been rather modest. Commercially available haptic devices remain bulky, inefficient, and expensive. For virtual surgery to fulfill its promise, major research advances must be directed in developing novel technologies for both kinesthetic and tactile feedback devices and their full integration within immersive environments generated using HMDs.

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Training and credentialing in laparoscopy, including the Fundamental Use of Surgical Energy

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INTRODUCTION TO LAPAROSCOPIC TRAINING

Medical school

Education of laparoscopic surgery can begin as early as medical school. Medical students gain exposure to various surgical scenarios during clinical rotations, or sometimes as early as the first and second years. In addition, many schools now offer intensive preparatory electives—or “Boot Camps”—to senior students to prepare for the residency years ahead.³ Boot camps are often developed based on basic skills as defined by the American College of Surgeons (ACS) and Association of Program Directors in Surgery (APDS) national curriculum. Courses may include didactic sessions; basic technical skills, such as knot tying and suturing; procedural skills involving Foley catheters, nasogastric tubes, central lines, chest tubes, and basic laparoscopy or endoscopy; and simulated patient scenarios.

Boot camp courses have increased student confidence relating to technical skills and clinical knowledge. A study by Naylor et al. demonstrated that trainees are capable of becoming proficient in technical skills for laparoscopic surgery as early as medical school. In this study, all students who completed the curriculum achieved beyond the passing scores required for Fundamentals of Laparoscopic Surgery (FLS) certification.¹⁸ This is beneficial for students particularly interested in surgery. Given work-hour restrictions during residency, the additional exposure and early practice provide residents a head start. Kolozsvari et al. compared FLS scores of incoming residents from 2003 to 2008 and revealed that scores have improved over time. Kolozsvari suggested that higher baseline FLS scores from incoming residents could be attributed to increased clinical exposure and laparoscopic simulation during medical school.¹³

Residency

Following medical school, formal skills training in general surgery is required. As of 2008, the American Board of Surgery (ABS) mandated that all general surgical programs have access to a skills lab.²⁷ Prior to this, in 2004 a survey by Korndorffer and colleagues documented that of 162 programs, only 55% had a skills lab. Moreover, only 55% of the programs with skills labs had mandatory training requirements—indicating that only approximately one-fourth of the 253 programs in the United States were conducting skills laboratory training using structured curricula.¹⁴ Many institutions have since adopted the surgical skills training developed by the ACS and APDS, intended to standardize training and to assure competency of surgeons.¹² The curriculum comprises three phases, which includes modules addressing basic skills, procedures of general and laparoscopic surgery, and simulated scenarios. Phase 1 teaches basic or core skills and tasks. This covers laparoscopic skills, tissue handling, suturing and stapling, dissection, central line placements, and colonoscopy. Phase 2 covers advanced procedures, such as laparoscopic appendectomy, hernia repair, and colon resection. In Phase 3, residents learn team-based skills such as laparoscopic troubleshooting or crisis, patient handoff, and trauma team training.

The FLS program, developed in 1997, was made a mandatory prerequisite for the ABS qualifying exam in 2008. This assured that graduating chief residents had, at minimum, the laparoscopic skills necessary for basic practice.

Fellowship

Surgeons who wish to continue training can undergo a fellowship in minimally invasive surgery. Fellowship is

obtained through the Fellowship Council. Historically, surgeons learned laparoscopy from short courses and mini-fellowships. As interest in laparoscopy grew, the pioneers in laparoscopic surgery formed the Minimally Invasive Surgery Fellowship Council and established a formal accreditation and match process. Today, there are over 150 programs nationwide.⁶

Fellowship allows surgeons to gain experience in advanced or specialty procedures that may not be adequately covered during residency. Due to work-hours limitations, it may be difficult to achieve adequate case volumes that are required by the Accreditation Council for Graduate Medical Education (ACGME) during residency. It is estimated that up to 80% of surgical residents seek postgraduate fellowship.²⁵

Fellowship is available in various disciplines, including advanced gastrointestinal surgery, endoscopy, minimally invasive surgery, bariatric/metabolic, hepatobiliary, colorectal, and thoracic surgery. As technology advances and newer techniques develop, fellowship programs are evolving to include dedicated robotic surgery. Current programs range from 1 to 3 years in length, with often 1–2 years being composed of research.

Practicing surgeons

Practicing surgeons can further advance training by participating in courses or mini-fellowship. These courses can last from half a day to several weeks and are offered globally. The first courses for laparoscopy emerged following the advent of the laparoscopic cholecystectomy in the late 1980s and the early 1990s.²⁷ Courses are also offered by the industry or societies, such as the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES), American Society for Metabolic and Bariatric Surgery (ASMBS), American Society of Colon and Rectal Surgeons (ASCRS), ACS, and others. The courses usually combine a didactic component, with hands-on cadaver or vivarium training, and/or direct surgery observation (Table 32.1).

Modalities

Training in laparoscopic techniques is conducted through various modalities. Training that is hands-on and

interactive leads to an active learning experience that is efficient and relevant.¹¹ Research has shown that surgeons have two learning styles: bodily-kinesthetic and spatial.³¹ Thus, surgical training has been conducted in the operating room through observation and participation. Eventually, competence is achieved through exposure time and high case volume.

However, due to safety concerns and limitations on work hours, training has shifted toward surgical simulation with objective measures.¹⁷ Simulation allows skills used in the real setting to be practiced in a safe and controlled environment. The educational value of simulation is most beneficial when skills are transferrable to the real, clinical setting.⁸ The most organized programs for standardized simulation training in laparoscopy have been the FLS, the Fundamentals of Endoscopic Surgery (FES), and the emerging Fundamental Use of Surgical Energy (FUSE) programs.

Fundamentals of Laparoscopic Surgery

The FLS is a training program developed by SAGES in the 1990s. FLS was designed as a standard set of educational material to teach fundamental knowledge and skills for basic laparoscopic surgery. FLS is currently used as a teaching and assessment tool. In 2005, FLS became co-sponsored by the ACS and SAGES and has been adopted as a prerequisite for the ABS qualifying examination. Increasingly, FLS is being used as a credentialing benchmark by health-care institutions and malpractice insurance providers.²

The FLS program includes an educational and assessment component. The teaching component comprises two parts: a didactic learning module and manual skills training (Figure 32.1). The curriculum is web based and contains study guides and didactic modules. Rather than focusing on specific procedures, the curriculum teaches general concepts and decision-making skills that can be applied to general surgery, gynecology, urology, and other surgical subspecialties. The modules include Preoperative Considerations,

Table 32.1 Training modalities for laparoscopy/endoscopy by level of education

Level of training	Training modalities for laparoscopy/endoscopy
Medical students	Boot camp
Residents	FLS, FES, FUSE, clinical cases, vivarium lab
Fellows	FLS, FES, FUSE, clinical cases, mini-courses
Practicing surgeons	FLS, FES, FUSE, mini-courses, mini-fellowships



Figure 32.1 FLS training box with video screen.

Intraoperative Considerations, Basic Laparoscopic Procedures, Postoperative Care and Complications, and Manual Skills Practice. Upon completion, a proctored web-based exam is taken in a designated testing center.⁸

The manual skills part consists of five tasks performed in a box trainer: peg transfer, cutting/dissecting, ligating loop, and suturing with intracorporeal or extracorporeal knot tying (Figure 32.2). Adapted from the MISTELS program, these tasks represent fundamentals of laparoscopic surgery. Tasks are measured in time, precision, and number of errors committed. Training may generally take 45–60 minutes to complete the exercises. One study demonstrates that skills acquisition can be achieved by novices in 9.7 hours of training and 119 repetitions.²³ A cut-off score of 270 was selected for a sensitivity and specificity of 82%.⁷ FLS certification is awarded after passing the final exam and technical skills.

A system that is used for high-stakes examination must be valid and reliable. Fundamental skills must be carefully chosen so that performance is measurable and can be validated. Both MISTELS and FLS have been extensively studied for reliability and validity. The interrater reliability was 0.998, and test-retest reliability was 0.892. Evidence from validation studies demonstrates that scores correlate with experience, and scores improve over time.^{5,9} In addition, FLS training allows transfer of skills to real operation. Skills from FLS training appear to be durable. One study shows that interval training can facilitate retention of skills for as long as 2 years after FLS certification.¹⁶ Furthermore, biannual training sessions to proficiency levels for surgical residents confer retention of skills out to 1 year.³⁰

Fundamentals of Endoscopic Surgery

The FES is another program developed by the SAGES. FES is currently the only standardized examination of knowledge

and skills for flexible endoscopy. The goal of FES is to teach technical and clinical judgment skills fundamental for performing gastrointestinal endoscopic surgery. Despite the clinical exposure in residency, there was a lack of general consensus for the minimum number of cases required to achieve competency for endoscopy.²⁸ The notion that surgeons lack adequate training in endoscopy emphasized the need for standardized training, leading to the development of FES.¹⁰

The development of FES was mirrored after FLS and was incorporated with lessons learned from the validation process of FLS. The FES program includes a web-based didactic course, a written examination, and a manual skills assessment with a virtual reality simulator.²⁸ The didactic component covers the following content areas: endoscope technology and equipment, patient preparation, sedation, general gastrointestinal endoscopy, and endoscopic therapies. The FES program currently does not cover advanced procedures such as endoscopic retrograde cholangiopancreatography and endoscopic ultrasound.¹⁹ After completion of the didactic course, a written examination must be completed to assess knowledge and clinical judgment.

The manual portion applies fundamental skills required for flexible endoscopy, which are assessed through a series of tasks performed using a virtual reality simulator. The fundamental skills assessed are (1) scope navigation, (2) loop reduction, (3) retroflexion, (4) traversing a sphincter, (5) management of insufflation, (6) mucosal evaluation, and (7) targeting. These skills are practiced by performing the following tasks: navigation and advancement through the colon using two-handed scope manipulation; identification and reduction of loops in the colon; retroflexion of the scope and targets in the stomach; evaluation of the mucosa of the colon; and use of biopsy forceps to examine and hold targets in a simulated colon.¹⁰

The FES program also includes both written and technical skills examination. After completion of the didactic course, the written examination is completed to assess knowledge and clinical judgment. Unlike the FLS, the tasks are scored electronically by the simulator. Nonetheless, the skills test is proctored and can only be completed at designated testing centers.²⁸

Both cognitive and manual assessments must be successfully completed, in addition to a valid physician license, for obtaining FES certification.¹⁹ As of March 2014, FES certification is required prior to obtaining board certification by the ABS.

The validity of FES has been established by many studies. The hands-on skills assessment was validated in a study of 160 naive participants by Vassillou et al.²⁸ The FES test showed 0.82 internal consistency reliability. In addition, the scores have 0.73 correlation with experience. The retest reliability showed an intraclass correlation of 0.85. The predictive validity of the FES was also demonstrated by Mueller et al. In this study, live colonoscopy was performed, followed by the FES hands-on test. Live cases were evaluated



Figure 32.2 Peg transfer task of FLS manual skills.

with the Global Assessment of Gastrointestinal Endoscopic Skills—Colonoscopy (GAGES-C), which were compared to the computerized scoring system of the FES simulator. A strong correlation of 0.78 was found between the GAGES-C score and the FES score. In addition, the participants who scored greater than 15 in GAGES-C were more likely to pass the FES manual test.¹⁷

Fundamental Use of Surgical Energy

FUSE is another program also launched by the SAGES. Developed by a multidisciplinary team of surgeons, anesthesiologists, and engineers, the purpose of FUSE is to increase education and training in safe operation and optimal use of electrosurgical instruments. Today, electrosurgery is commonly used to perform a multitude of tasks from maintaining hemostasis to coagulation or dissection.²⁶ These energy devices can lead to iatrogenic complications, such as accidental tissue injury and operating room fires. These complications are partly attributed to the lack of understanding about device function and safety. A survey of surgeons demonstrated that approximately 31% of surgeons did not know how to handle fire on a patient, 31% could not identify the device least likely to interfere with a pacemaker, and 13% were not aware that thermal injury can extend beyond a bipolar instrument.⁴ FUSE was developed in an effort to address the knowledge gap associated with energy devices.¹⁵

FUSE consists of a standardized curriculum and a validated certification examination. The curriculum covers 10 domains of electrosurgical instruments. The domains are (1) fundamentals of electrosurgery, (2) mechanisms and prevention of adverse events, (3) monopolar devices, (4) bipolar devices, (5) radiofrequency for soft tissue ablation, (6) endoscopic devices, (7) ultrasonic energy systems, (8) microwave energy systems, (9) energy devices in pediatric surgery, and (10) integration with other medical devices.¹⁵ The FUSE program now also includes a comprehensive textbook manual as well as a web-based multimedia curriculum.

Other laparoscopic training programs

Additional training can be conducted using basic box trainers. At UT Southwestern's Simulation and Training Laboratory (Dallas, Texas), "Southwestern (SW) stations" are set up using Karl Storz video-trainers. Using a validated curriculum of tasks, such as bean drop, running string, checkerboard, block move, and suture foam, trainees can practice basic technical skills for laparoscopy. Training is completed as self-paced, while logging performance metrics until proficiency are reached.²⁴

There are several advantages of video simulator stations. SW stations use fewer consumables and thus have less training costs compared to FLS. In addition, SW stations



Figure 32.3 Cost-effective training box for laparoscopic manual skills testing, using a low-cost platform and personal phone camera.

can be used to supplement the FLS curriculum. A study conducted by Rosenthal et al. demonstrated that when pre-training with the SW stations was completed, the training time for the FLS decreased. Trainees were able to achieve competence faster than those who did not pre-train with SW stations.²¹ Other laparoscopic training programs that are supplemental or parallel to FLS include the Rosser Top Gun Training Program.²² In addition, independent platforms using simple off-the-shelf technology provide the ability to practice laparoscopic skills without the expensive videoscopic equipment, thereby reducing the cost of training (Figure 32.3).

Clinical

As trainees achieve competence in skills via simulators, surgeons are expected to gain real experience with live operations. When performing live operations, validated assessment tools are used to measure skill and performance. There are two commonly used tools: the Objective Structured Assessment of Technical Skill (OSATS) and the Global Operative Assessment of Laparoscopic Skills (GOALS). OSATS is a global rating scale for technical skills associated with laparoscopy. In 1997 at the University of Toronto, Reznick et al. introduced the OSAT.²⁰ This was a

seven-item table of technical performance on a five-point grading scale. The items included respect for tissue, time and motion, instrument handling, knowledge of instruments, use of assistants, flow of operation/forward planning, and knowledge of the specific procedure. The OSAT was measured against a simple pass/fail judgment and procedure-specific criteria. The interrater reliability for the OSAT was moderate to high and demonstrated construct validity for both live and bench models.

GOALS is an objective assessment tool to measure intra-operative laparoscopic skills. GOALS includes a 5-item rating scale, 10-item checklist, and two visual analogue scales. Vassiliou and Fried et al. developed this tool based on Reznick's OSAT specifically for minimally invasive procedures. This was a five-point global rating skill analyzing depth perception, bimanual dexterity, efficiency, tissue handling, and autonomy. "Anchor" descriptions of the five-point Likert scale for each skill were placed at scores of one, three, and five to aid the evaluator in assessment and decrease the need for evaluator training. In one study, 21 participants performed a laparoscopic cholecystectomy and were scored with GOALS. There was an intra-class correlation coefficient (ICC) of 0.89 between two trained observers, 0.82 between observers and attending surgeons, and 0.70 between participants and attending surgeons. The data suggested this tool was both reliable and valid.²⁹

The ACGME requires residents to perform a minimum of 750 procedures during residency, with 150 cases performed in the chief resident years. Of these cases, 60 cases must be basic laparoscopic procedures, and 25 cases must be complex laparoscopic procedures. Eighty-five cases must also be endoscopic, including 35 upper endoscopy and 50 colonoscopy. The resident must be involved in a significant portion of patient management, such as diagnosing, preoperative care, selection and accomplishment of the operative procedure, and postoperative care. Currently, global assessments adapted from tools such as OSATS and GOALS are being applied as training assessments for certain index cases.

In addition to the minimum category numbers, procedure-specific training may also be provided by individual programs. Procedural education can be obtained through workshops, which typically include a didactic lecture, animal lab, and observation of live surgery.

Credentialing

Credentialing refers to the written documentation of specific training or experience, although the term *credentialing* does not necessarily attest competency.¹

Credentialing requirements in order to perform laparoscopic surgery can vary per institution. Each hospital or institution is responsible for granting privileges at its location. When an applicant is seeking credentialing, a credentialing committee is formed and reviews the applicant's background. Typically, board certification,

completion of residency, and experience are considered in the privileging process. Some institutions may require FLS certification for credentialing, as it is also required as a prerequisite for certification by the ABS. FLS certification is also recommended by national societies, such as ACS and SAGES.

Many hospitals and institutions adopt credentialing recommendations by national societies. For example, SAGES has created Guidelines for Institutions Granting Privileges Utilizing Laparoscopic and/or Thorascopic Techniques. These guidelines are created based on established data or the consensus of expert opinion, allowing uniformity of standards. According to SAGES, privileging for laparoscopic or thorascopic should be the responsibility of each institution, with the recommendations of the chief of surgery. Formal residency training is required, with formal training in laparoscopy and/or thorascopy or practical experience. Once competence and privileges have been established, continuing medical education should be required for renewal.

New developments

As technology advanced, simulation in the form of virtual reality has become possible. Virtual reality incorporates real-world settings to be mimicked in a three-dimensional computer interface, allowing users to interact and navigate and to be immersed in the simulated scenario (Figure 32.4). A version of this is already implemented in the FES curriculum. There is increasing interest in more cost-effective approaches to training. Cheaper, lower-fidelity approaches to laparoscopic simulation may be just as effective as expensive computerized simulations. The reliability, feasibility, and validity of these training tools and systems remain a topic of discourse among stakeholders in surgeon training and quality care.

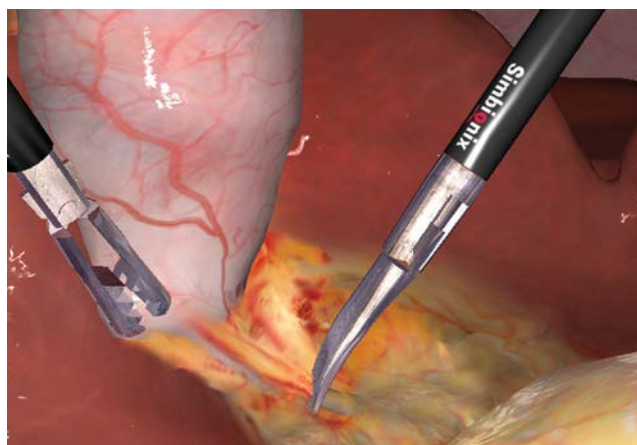


Figure 32.4 Virtual reality simulation for laparoscopic cholecystectomy (Simbionix, Littleton, Colorado).

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Measuring quality in minimally invasive surgery

ELAN R. WITKOWSKI AND MATTHEW M. HUTTER

WHY MEASURE SURGICAL QUALITY?

The average American will undergo nine surgical procedures in their lifetime, including three inpatient operations.¹ While the intent of these interventions is to prolong and improve life, the practice of surgery is yet to be perfected, and many patients still suffer complications. The impact of a complication can range from minor to devastating, and up to 1% of these procedures may lead to a patient death.

By recognizing the scope of potential harm from surgical complications, the logical next step is to try to improve outcomes. The rise of minimally invasive surgery is a testament to the efforts of pioneers who sought to improve upon open techniques. Widespread adoption of minimally invasive surgery has been one of the key drivers in improving surgical quality and patient outcomes in recent years.

In the field of quality improvement, there is a commonly reiterated quotation paraphrased as follows: “If you cannot measure it, you cannot improve it.” And while management and quality improvement are certainly more nuanced than the quotation implies, there is a great deal of truth to the idea that careful collection of data can be a powerful tool to improve outcomes.

Reliable data collection can lead to continuous quality improvement. By identifying complications and recording data related to these outcomes, resources can be directed toward improving outcomes in many ways, including

- Identifying high-risk procedures
- Identifying vulnerable populations or patient factors that contribute to poor outcomes
- Identifying variation in rates of complications
- Identifying providers or facilities with superior or sub-optimal outcomes

In addition to quality improvement, data collection and quality measurement are critical for informed decision-making. For the surgeon, this can inform the choice of

procedure, patient selection, management strategies, and surgical techniques. Similarly, patients and their referring providers can use such data to help them decide whether surgery is right for them, which procedure they would prefer, and which surgeon they should choose.

STAKEHOLDERS IN QUALITY IMPROVEMENT

Patients are the ultimate stakeholder in health care and function as increasingly educated consumers and decision makers. Individual patients and groups advocating on their behalf have pressed for data transparency as they seek quality and value within a complex marketplace. Public reporting continues to gain traction and, in many cases, has become required.

Similarly, payers have created innumerable plans to move patients and dollars toward higher-quality, lower-cost care. The incentive for these efforts is clear and will likely only intensify with time. Tiering, Accountable Care Organizations (ACOs), bundled payments, meaningful use, and many other programs use quality metrics and risk adjustment to determine payment.

Many of these plans have been criticized for using inappropriate or inaccurate metrics. Yet it seems inevitable that surgeons will be publicly described, evaluated, and reimbursed using data and quality metrics. We must therefore ensure that these measures are appropriate, meaningful, and accurate.

DEFINING SURGICAL QUALITY

According to the Institute of Medicine,² patient care should be

- Safe
- Effective
- Patient centered

- Timely
- Efficient
- Equitable

Current metrics often do not take into account what most surgeons would define as overall quality for patients. For example, using a skin clipper instead of a razor, giving antibiotics within a specific time interval, and performing a medication reconciliation are all important, but many surgeons would not consider these to be key determinants of outcomes or quality.

In practice, there are many factors that determine overall “quality.” Quality spans multiple different domains, and each needs to be examined to fully evaluate surgical care. These include the following:

- Appropriateness
- Patient satisfaction/experience
- Patient-centered outcomes
- Patient-reported outcomes
- Functional outcomes
- Longer-term outcomes
- Clinical effectiveness
- Efficiency
- Value

To generate meaningful quality metrics, surgeons must continue to work with statisticians, methodologists, informatics specialists, and policy makers.

HISTORICAL CONTEXT

Measuring quality is not a new concept. Ernest Amory Codman (a surgeon and cofounder of both the American College of Surgeons and the predecessor of the Joint Commission on Accreditation of Healthcare Organizations [JCAHO]) proposed what he called the End Results System over 100 years ago.³ It was an idea before its time.

Codman is quoted as saying the following:

So, I am called eccentric for saying in public: that hospitals,
if they wish to be sure of improvement,
Must find out what their results are.
Must analyze their results, to find their strong and weak
points.
Must compare their results with those of other hospitals...
Must welcome publicity not only for their successes, but
for their errors...
Such opinions will not be eccentric a few years hence.

Now, over 100 years later, we are still trying to measure quality well.

Shortly after the enactment of Medicare and Medicaid in 1965, the newly formed Health Services Research Section of the U.S. Public Health Service convened a group of experts to discuss factors influencing public health and health-care quality. This conference led to the publication of a landmark paper in 1966 by Avedis Donabedian, which

described a framework for assessing health-care quality.^{4,5} Donabedian’s framework remains a fundamental pillar for much of today’s work and divides the study of quality into measures of structure, process, and outcomes.

QUALITY MEASURES

Using the paradigm of structure, process, and outcomes is a common first step for studying the elements of quality.⁶ While many elements of health care cannot be neatly categorized, this is a helpful tool to organize quality improvement initiatives.

Structure

Structural variables describe organizational structures, qualities of the staff or hospital, physical environment, etc. These are relatively easy to measure, and administrative data provide a readily available source. Numerous studies have examined provider and hospital volume as a structural metric. Hospital classification is another structural variable, such as accreditation of bariatric programs by the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP) or National Cancer Institute (NCI) designation of cancer centers.

Several important limitations of structural variables exist. Confounding is commonly seen, such as in the example of a subspecialized surgeon with high procedure volume who also operates at an NCI-designated cancer center. In addition, structural variables are often difficult to modify, and their association with outcomes is often not causal.

Process

Process measures reflect the care that patients receive. Examples include the completion of a medication reconciliation or giving antibiotics within 1 hour before incision. Like structural variables, they can be quantified relatively easily, although measurement at the patient level can be more cumbersome.

Process measures are easier to modify than structural components of care. For that reason, they are attractive targets for quality improvement projects. While they may seem relatively easy and inexpensive to measure, they are often labor intensive and costly to modify.

Surgical Care Improvement Project (SCIP) measures, a bundle of process measures that include timely administration of perioperative antibiotics and removal of urinary catheters, were widely adopted in the United States. Initiated in the early 2000s by the Centers for Medicare and Medicaid Services (CMS) and the Centers for Disease Control and Prevention (CDC), the goal of this multiorganizational effort was to reduce surgical site infections by 25% by the year 2010. While reported rates of adherence to SCIP

measures improved substantially over time, the expected improvement in outcomes was not fully realized.⁷ The Joint Commission has subsequently phased out some of the original SCIP measures as part of their ORYX performance measurement initiative.

Enhanced Recovery After Surgery (ERAS) protocols have become increasingly common in minimally invasive surgery. Much of the pioneering work in colorectal surgery has been recently applied to other fields such as thoracic, bariatric, and hernia surgery. An important component of these protocols is the implementation of processes, which lend themselves to measurement. However, the individual contribution of each component to patient outcomes is difficult to discern.

Outcomes

Outcomes are the ultimate target of quality improvement at a patient level. Examples of outcomes measures include length of stay, cost, morbidity, mortality, reoperation, weight loss after bariatric surgery, and R0 resection. Patient-reported outcomes, such as pain, satisfaction, and level of function, are an area of increasing focus.

The importance of improving outcomes is clear to all stakeholders. They are simple to understand, and it is usually easier to get surgeon “buy-in” when discussing these measures. However, measured outcomes can be misleading, and there are multiple contributors to outcomes that need to be accounted for.

Outcomes can be broken down to patient factors, treatment effectiveness, quality of care, and random chance. Risk adjustment can control for patient factors, benchmarking can control for treatment effectiveness, and statistical analysis can help minimize the role of random chance. Therefore, with appropriate risk-adjusted benchmarked outcomes with sound statistical analysis, we can help define the quality of care. The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) is perhaps the best-known surgical outcomes collection system in the United States ([Table 33.1](#)).

IMPROVING DATA MEASUREMENT

The usefulness of measuring, analyzing, and reporting data is fundamentally determined by the quality of data collected and the use of best practices. Several characteristics of high-quality data can include the following:

- Prospectively collected
- Standardized definitions
- Collected by trained and audited data collectors (who are not involved in direct patient care)
- Benchmarked
- Risk adjusted
- Analyzed with sound statistical methodology, and responsible conclusions drawn

Many sources of data exist, and the strengths and weaknesses of each should be carefully studied before

Table 33.1 Using structure, process, and outcomes to measure surgical quality, with examples, advantages, and disadvantages of each

	Structural	Process	Outcomes
Examples	Surgeon volume	Perioperative beta blockers	Morbidity and mortality rates
	Hospital volume	Antibiotics received within 1 hour of incision	Patient satisfaction
	Fellowship training	Receiving appropriate screening tests	Cost
	Computerized physician order entry	Discharge instructions given to patient	Length of stay
	Nurse-to-bed ratio		
Advantages	“Closed” intensive care unit		
	Quick and easy to collect	Evidence-based support from randomized trials	Reflect the ultimate goal of improvement
	Inexpensive to collect	Reflect care that patients actually receive	Easy “buy-in” from surgeons
Disadvantages	Strongly related to outcomes	Actionable—linked to quality improvement activities	Hawthorne effect—being observed and measured alone can improve outcomes
	Many variables not actionable	Must identify the correct patients	Sample size: few hospitals or surgeons have enough events or cases for statistically meaningful results
	Usually studied observationally (risk of confounding)	Labor intensive	Aggregated outcomes provide less information
	Imperfect proxies for outcomes (average results)	Major knowledge gap (few procedures have been studied, often in specific populations)	Takes time to collect
			Expensive to measure

Source: Adapted from Birkmeyer JD et al. *J Am Coll Surg* 2004;198(4):626–32.

drawing conclusions and making patient-care decisions. Administrative data can provide important clues into patterns of care and cost, with a relatively low burden of collection. Significant potential limitations include lack of longitudinal follow-up and clinically relevant variables.

The ACS NSQIP originated in the Veteran's Health Administration in the 1990s.^{8,9} Today it is used in hundreds of hospitals to collect patient-level outcomes data.¹⁰ The data are obtained directly from patient charts using standardized definitions, for a period of 30 days postoperatively. Reports can be obtained by participating hospitals, which include both risk adjustment and case mix adjustment. This process allows for more useful benchmarking and lets participants see both evidence of success and potential areas of improvement.

An important benefit of surgeon-led data collection programs is the inclusion of specific variables and outcome measures that may be useful for clinical improvement and risk adjustment. To create clinically rich outcomes databases with specialty-specific information, several additional quality programs have been created and widely deployed.

A good example in minimally invasive surgery is the MBSAQIP, which collects and reports data for over 95% of all bariatric cases in the United States, along with providing center standards and accreditation.¹¹ These specialty-specific or procedure-specific data sets allow for more

comprehensive analysis of the relevant structural, process, and outcome measures in patient populations. In theory, this should allow care to be analyzed in a more meaningful way and quality to be improved over time.

There are multiple similar efforts in fields where minimally invasive surgery is practiced: cardiothoracic, pediatric, hernia, and oncologic surgery, to name just a few. These efforts will continue to evolve as the need for quality data is balanced with the substantial resources required to collect, maintain, validate, and analyze the results. If the burden of participation is too high, participation may suffer, and the ability to collect generalizable data and make useful recommendations may be negatively impacted.

IMPROVING QUALITY OF CARE

While it is helpful to measure components of quality, the ultimate goal is to improve patient experience and outcomes. This can be a daunting task for surgeons and hospitals. Furthermore, it is important to avoid spending resources on programs that do not produce results.

Birkmeyer, Dimick, and Birkmeyer described a framework of recommendations to help focus quality improvement efforts based on the risk of each case compared to the frequency with which it is performed⁶ (Figure 33.1). This

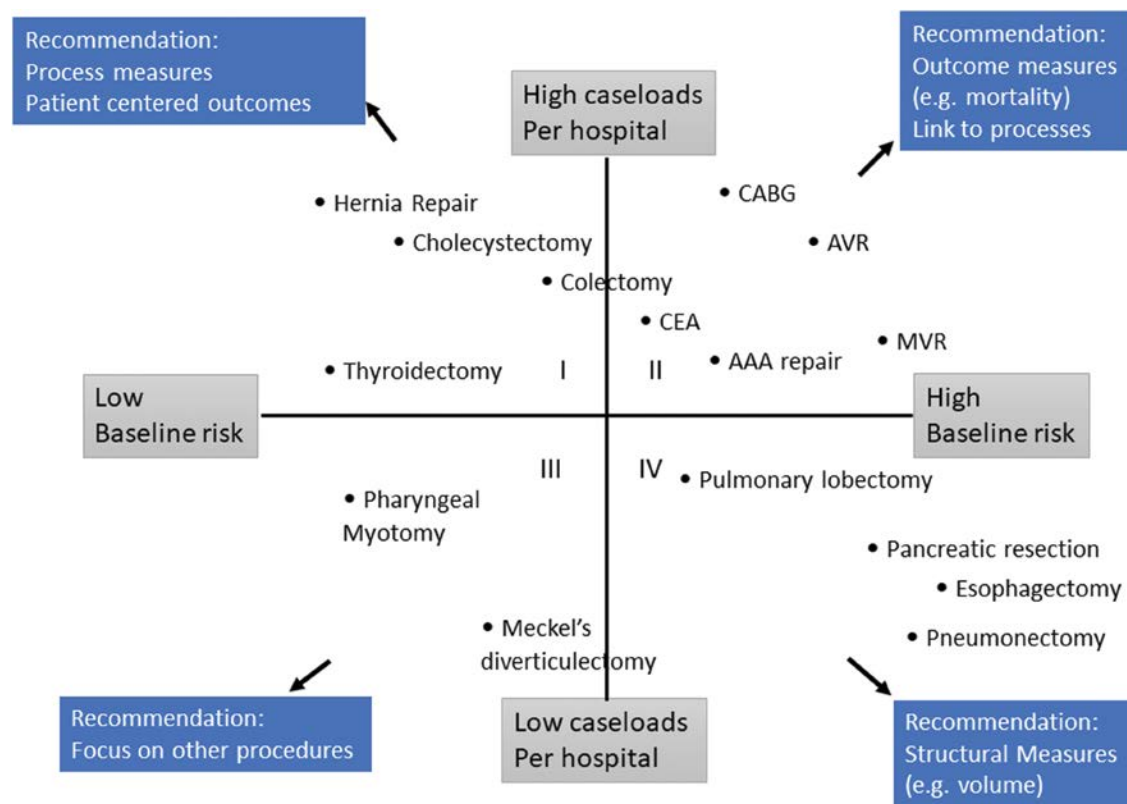


Figure 33.1 Recommendations for when to focus on structure, process, or outcomes. (Adapted from Birkmeyer JD et al. *J Am Coll Surg* 2004;198[4]:626–32.)

provides a pictorial metric of relative value. Many minimally invasive procedures fall in the left upper quadrant of the diagram: relatively low risk, but high volume. Using this schema, process measures and patient-centered outcomes become a focus of quality improvement interventions.

By recognizing that many minimally invasive surgery cases have low rates of serious complications or death (and that some of these may be unpredictable or unavoidable), the focus then shifts toward improving long-term outcomes, patient-reported outcomes, etc. It is also important to make sure that all patients are receiving a high level of care (i.e., process measures).

Unfortunately, some of the tools to do this well are still lacking. Administrative databases and clinical databases with short follow-up will not capture many of the comparative long-term effects of different hernia repairs, bariatric operations, etc. There is considerable ongoing work to create more meaningful metrics for the future. These might include some of the following:

- Patient-reported outcomes
- Functional status
- Symptom scores
- Longer-term outcomes
- Aggregated outcome metrics
- Composite measures

Collecting these types of data usually occurs within the context of clinical trials or institutional investigations. It is important that as a quality improvement tool, these metrics must be thoughtfully designed and validated. For example, patient-reported outcomes may need to be adjusted for socioeconomic and demographic factors, health literacy, and variable rates of reporting. They will also need to be implemented using a platform that can be collected reliably across a variety of settings with reasonable resources. If this can occur, accurate risk-adjustment and case-mix adjustment can take place along with meaningful benchmarking. This type of specific feedback may further drive the cycle of continuous quality improvement.

CONCLUSION

Measuring surgical quality is complex, but important to improve the consistency and outcomes of care. Data will

be increasingly used to publicly describe surgeons, direct patient referrals, and influence reimbursement. Traditional metrics are often not ideal for low-risk minimally invasive procedures. Many efforts have been made to improve the quality of data collected, as well as the robustness of risk-adjustment and case-mix-adjustment models. In the future, new patient-centered metrics and long-term data collection programs will be important to continue to improve care. Surgeons must pair with statisticians, data scientists, policy makers, and other experts to be involved in the development of programs for quality measurement by which we will be judged.

Most importantly though, surgeons must lead these initiatives. Surgeons need to determine what to measure and how to measure it. They must insist on good data, not claims data, and create data collection programs if they do not exist. They need to determine what signifies an outlier. Surgeons need to be proactive, rather than reactive. “If you are not at the table, you are on the menu.”

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How the commitment to patient safety impacts operative practice in minimally invasive surgery

ERIC LUEDKE, DAN AZAGURY, AND JOHN MORTON

INTRODUCTION

As surgeons, we have an utmost responsibility toward ensuring our patient's safety. With an estimated volume of 234 million operations performed worldwide every year, the safety and quality of surgical care have become a significant global health issue.¹ In 2000, the Institute of Medicine published the report "To Err Is Human," which called for a national effort to improve the safety of health care through systems-based initiatives.² Since the report's inception, there has been a sharp increase in interest in programs developed to decrease medical errors, especially in surgical care. In spite of these efforts, recent reports reveal that adverse event rates for surgical conditions remain high.³ Wang et al.⁴ showed that from 2005 to 2011, among patients hospitalized in the United States requiring a surgical procedure, the rate of occurrence of adverse events stayed steady at 3.2%–3.3%, the proportion of patients with one or more adverse event increased from 21.6% to 22.7%, and the number of events per 1,000 hospitalizations increased from 352.3 to 368.1. It is possible that the increasing complexity of health care and surgical procedures has resulted in a corresponding increase in the number of medical errors.⁵ In fact, complications related to operative care are responsible for 11% of total disease burden, of which nearly half is estimated to be preventable.⁶ Despite numerous efforts to improve patient safety, rates of errors and complications continue to rise nationwide.⁴

DEFINING QUALITY AND PATIENT SAFETY IN SURGERY

There is a high demand for patient safety and information on surgical quality. Well-informed and educated patients are seeking the highest possible quality of care. Payers are

seeking to reward the highest-quality providers (pay for performance) and direct selected patient populations to particular providers.⁷ However, despite this demand, there is little consensus on how to best measure surgical quality or compare surgical performance. Moreover, the definition of quality may vary between patients, physicians, society, administrators, and health-care policy makers.

Following the Institute of Medicine's report "To Err Is Human," several interventions have been introduced in the surgical setting to improve patient safety in surgery. These interventions have measured quality using various aspects of structure, process, or outcome.⁸ Recent initiatives implemented to improve patient safety include the Surgical Care Improvement Project and Universal Protocol by the Joint Commission, the World Health Organization's (WHO) surgical safety checklist, and the National Surgical Quality Improvement Program (NSQIP). However, in spite of these advancements, rates of errors and complications continue to rise nationwide, and we continue to lack a uniform system for reporting and analyzing surgical complications.⁴

Today, the health-care field has begun to look to other fields of high-risk endeavor for solutions, such as in the utilization of crew resource management that exists for airlines to improve team communication in the operating room. Other professions that have entrenched a strong culture of safety from which surgeons can model include nuclear technology, naval submarine technology, and aerospace engineering.³ As an example, NASA has developed a proven safety culture paradigm that involves detailed reporting of concerns without fear of reprisal, thereby learning from both successes and failures while simultaneously adapting to meet the demands of the field. Similarly, the U.S. Federal Aviation Administration has developed the amnesty program, designed to provide incentives for the reporting of errors and poor personal conduct. However, many in the

medical field remain reluctant to report medical errors publicly for fear of monetary penalties, medicolegal implications, and damage to their professional reputation.⁹

One measure of patient safety that may be particularly useful is the rate of in-hospital preventable adverse events (PAEs), or preventable injuries caused by medical care. PAEs have been linked to higher mortality rates and increased lengths of stay. The Agency for Healthcare Research and Quality (AHRQ) has developed a set of quality indicators to measure PAE during hospitalization, known as the patient safety indicators (PSIs) (Table 34.1).

PSIs may be applied to administrative or billing databases. These indicators identify populations at risk for an event based on *International Classification of Diseases, Ninth Revision* codes, diagnosis-related group codes, and type of hospital admission. These data are being used to identify potential lapses in quality health-care delivery and for benchmarking different areas of health-care delivery. In other words, they present readily available, benchmarked quality outcomes for hospitals that can provide a first-pass examination of hospital-based outcomes. Given their advantages, including ease of use, PSIs are becoming an international standard seen in hospital dashboards, federal reports, and international comparisons.

There are disadvantages to using PSIs as a quality indicator. The sensitivity of AHRQ PSIs may be lower than other quality metrics due to their direct dependency on the accuracy of the data entered. Preexisting conditions may further confound and influence the rate of PSIs if these are counted as a PSI. In addition, PSIs employ data that may not

be clinically relevant and that were collected for purposes other than to measure the quality of patient care.¹⁰

Our group has successfully used PSIs as benchmarks to evaluate the quality of surgical care of open versus laparoscopic gastric bypass patients.¹¹ In this population-based study, laparoscopic surgery resulted in superior patient outcomes including mortality, length of hospital stay, complications, and PAEs. All PSI rates were significantly higher for patients who underwent an open gastric bypass procedure. In particular, laparoscopic surgery had significantly fewer risk-adjusted events for the following: failure to rescue, postoperative hemorrhage or hematoma, postoperative respiratory failure, postoperative pulmonary embolism or deep vein thrombosis, and accidental puncture or laceration.

Comparatively, Peterson et al.¹² recently published a study examining patients who underwent open or laparoscopic colorectal resections. Likewise, they found that the prevalence of any PSI was lower in the laparoscopic group (4.2 versus 8.3%; $p < 0.001$). Multivariate analyses showed that the likelihood of any PSI for laparoscopic colorectal resection was 57% lower than for open resections. They concluded that laparoscopic colorectal surgery is associated with a lower risk of adverse patient safety events than open surgery.

FACTORS AFFECTING PATIENT SAFETY

Vigorous efforts are required to eliminate or reduce the frequency of adverse patient outcomes. Patient safety in surgery is defined as safety from all adverse outcomes and should not be limited to only preventable errors or sentinel events. Plainly put, an adverse outcome jeopardizes patient safety, independent of whether the outcome was preventable or not. As such, improving the quality of surgical care mandates reducing the incidence of adverse outcomes, ultimately improving patient safety.¹³

Many factors are contributory to the safety and quality of care of our patients. Emergency operations, technically challenging cases, more than one primary procedure or surgeon, intraoperative team turnover, intraoperative distractions (pagers, phone calls, and side conversations), and time pressures to start or complete the procedure are all confounding factors that have the potential to affect patient safety.¹⁴ As surgeons, we place a great deal of emphasis on our surgical precision and technique. Interestingly, however, multiple studies have shown that adverse events from surgical procedures are much more frequently related to errors occurring before or after the procedure than by a technical mistake made during the operation.³ These include diagnostic errors leading to misdiagnosis-related patient harm,¹⁵ delay in treatment or failure to treat,¹⁶ and communication breakdowns leading to adverse patient outcomes.¹⁷

Teamwork and communication are essential to the promotion of patient safety and high-quality care. Creating a culture of safety through implementation of these measures

Table 34.1 Agency for Healthcare Research and Quality (AHRQ) Patient safety indicators

Complications of anesthesia
Death in low-mortality DRGs
Decubitus ulcer
Failure to rescue
Foreign body left in during procedure
Iatrogenic pneumothorax
Selected infections due to medical care
Postoperative hip fracture
Postoperative hemorrhage or hematoma
Postoperative physiologic and metabolic derangements
Postoperative respiratory failure
Postoperative pulmonary embolism or deep vein thrombosis
Postoperative sepsis
Postoperative wound dehiscence in abdominopelvic surgical patients
Accidental puncture and laceration
Transfusion reaction
Birth trauma—injury to neonate
Obstetric trauma—vaginal delivery with instrument
Obstetric trauma—vaginal delivery without instrument
Obstetric trauma—cesarean delivery

in and outside of the operating room is the responsibility of the surgeon and is absolutely necessary to improve patient safety and quality outcome measures.¹⁸ Catchpole¹⁹ analyzed the effects of surgical, anesthetic, and nursing teamwork skills on technical outcomes using a four-dimensional scaling system consisting of leadership and management, teamwork and cooperation, problem-solving and decision-making, and situational awareness. Operating time, technical errors, and other procedural problems were all inversely correlated with effective teamwork and communication scores. This supports the concept that interventions to improve teamwork and communication may have significant beneficial effects on patient safety and outcome. Additionally, in the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) study, communication was identified as the most common root cause of sentinel events involving wrong-site surgeries.²⁰ JCAHO subsequently identified additional system and process-based factors that may contribute to an increased risk of wrong-site surgery.²¹

Surgeon-specific factors are also important in eliminating or reducing adverse patient outcomes. Surgeon stress, fatigue, and sleep deprivation may potentiate surgical error. As an example, a recent study found an increased rate of surgical complications when physicians had slept less than 6 hours.²² Other factors to consider include the importance of surgeon experience, subspecialization, and center accreditation on patient safety and surgical quality outcomes. As an example, a key component to quality improvement in bariatric surgery has been the accreditation process as implemented by the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program. The accreditation program of the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program provides an ideal platform for quality improvement by maintaining a clinically derived data registry with the ability to benchmark results and track outcomes longitudinally. The accreditation process has been proven to save lives, lower complications, increase access, and decrease costs.²³

IMPORTANCE OF INNOVATION AND MINIMALLY INVASIVE SURGERY

As noted above, minimally invasive surgery is a powerful quality improvement tool and has demonstrated its efficacy in reducing mortality and morbidity. Its increased adoption still has the potential to significantly impact patient safety and quality care. As studies have demonstrated, the application of minimally invasive surgery has led to improved patient outcomes. As an example, Weller et al.²⁴ compared the outcomes of open versus laparoscopic gastric bypass surgery. After adjusting for patient and hospital factors in over 19,000 patients, those who underwent open surgery were more likely to experience reoperation and complications (pulmonary, $p < 0.001$; cardiovascular, $p < 0.02$;

procedural, $p < 0.01$; sepsis, $p < 0.001$; anastomotic leak, $p = 0.03$). Quality of life scores have also been shown to be improved following the application of minimally invasive techniques.²⁵ There remains some belief that surgical innovation could compromise patient safety and quality care. To the contrary, with innovation driven by the desire to improve the safety of our patients, it should be expected that innovation will only be beneficial at improving patient safety and quality care outcome measures.²⁶ Because patient safety and quality outcome measures have become important criteria by which surgical care is evaluated, it is our surgical responsibility as leaders in the field of minimally invasive surgery to take the lead in the effort to improve the care of our patients. Future studies should focus on factors that promote the safe adoption of innovative surgical techniques and optimize surgical outcomes.

One area of particular interest is the application of enhanced recovery programs to improve quality outcome measures. Enhanced recovery programs are gaining in widespread popularity in the United States after being widely adopted in Europe, with the goal of developing the optimal perioperative care pathway by means of literature review and adaptation of treatments to give the best fit throughout the patient's journey. Multiple studies have validated the use of enhanced recovery pathways. Zhuang et al.²⁷ performed a recent meta-analysis of randomized controlled trials looking at enhanced recovery after surgery programs versus traditional care in colorectal surgery. In comparison with traditional care, enhanced recovery after surgery programs were associated with significantly decreased primary hospital stay (weighted mean difference, -2.44 days; 95% CI, -3.06 to -1.83 days; $p < 0.00001$), total hospital stay (weighted mean difference, -2.39 days; 95% CI, -3.70 to -1.09 days; $p = 0.0003$), total complications (relative risk, 0.71; 95% CI, 0.58–0.86; $p = 0.0006$), and general complications (relative risk, 0.68; 95% CI, 0.56–0.82; $p < 0.0001$). Importantly, there were no significant differences found for readmission rates, surgical complications, or mortality. A recent multicenter prospective study with retrospective controls was published by Esteban et al.²⁸ comparing fast track or conventional post-operative care following laparoscopic or open elective surgery for colorectal cancer. Not surprisingly, the combination of laparoscopy with a fast track protocol versus conventional care resulted in significantly shortened hospital stay (5 days versus 9 days; $p < 0.001$) in addition to less overall patient complications (22% versus 30.4%; $p < 0.009$). Plainly put, the implementation of an enhanced recovery pathway in combination with minimally invasive techniques will result in improved patient safety and quality outcome measures. A systematic review and meta-analysis of enhanced recovery programs in surgical patients was recently conducted by Nicholson et al.²⁹ Thirty-eight trials were included in the review with over 5,000 patients. The presence of an enhanced recovery program reduced the primary length of stay (standardized mean difference -1.14) and reduced the risk of all complications within 30 days (relative risk, 0.71).

FUTURE DIRECTIONS

As physicians, hospitals, and health-care organizations continue to improve data collection and recording of quality outcome measures, interpretation and auditing of this information become essential. The creation of a surgical dashboard for quality has proven to be beneficial for tracking quality outcome measures, identifying areas of needed improvement, and auditing system changes to improve patient safety.⁶ One of the dashboard's greatest strengths lies in its ability to link improvement programs, thereby enabling continuous tracking of institutional performance with the unique ability to benchmark one's own performance against that of similar groups. While integration of a surgical quality dashboard faces future challenges, the value of investing in a system proven to decrease medical errors, improve patient safety and quality of care, and ultimately improve patient outcome measures is invaluable. Developing a unified way to assess surgical quality and propagation of a culture of safety in surgical care should be of utmost importance as we proceed throughout the twenty-first century. It will be up to us as leaders and role models to continue to emphasize patient safety and to continue to make improvements in the surgical field that lead to improved patient outcomes.

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Three-dimensional transesophageal echocardiography in minimally invasive cardiac surgery

MARIO MONTEALEGRE-GALLEGOS AND FEROZE MAHMOOD

INTRODUCTION

At the end of the eighteenth century, an Italian monk named Lazzaro Spallanzani made an amazing observation. He saw that in contrast to owls, bats could fly comfortably in the dark without colliding with any objects. He postulated that an inaudible sound allowed bats to navigate in darkness.¹ The sound described by Spallanzani is now known as ultrasound, and the same fundamental principles that allow bats to locate objects by the echoes they generate are used today in ultrasound image acquisition.

Ultrasound imaging of the heart and great vessels (i.e., echocardiography) has been instrumental for the advancement of cardiology and cardiac surgery. Echocardiography allows for a detailed visualization of intracardiac structures and provides qualitative and quantitative information for assessing global and regional cardiac function. Furthermore, the development of minimally invasive therapies for cardiovascular disease has increased the importance of echocardiography during procedural guidance, and a contraindication to echocardiography may be an impediment to perform a planned minimally invasive procedure.²

Several echocardiographic modalities have been used during minimally invasive surgery, but transesophageal echocardiography (TEE) is by far the most commonly used in the perioperative period, mainly due to its high image quality and that it can be positioned at a distance from the operative field.

In this chapter, we describe the basic principles of three-dimensional (3D) TEE and its current role in minimally invasive cardiac surgery. We also discuss some of the potential future applications of 3D TEE.

BASIC PRINCIPLES OF TEE

Sound waves are longitudinal pressure waves that propagate through a series of compressions and rarefactions of the medium, without a net particle displacement. Ultrasound waves are sound waves that have a high frequency (oscillations per second), usually $>20\,000$ Hz, and cannot be perceived by the human ear.

An ultrasound transducer is composed of a series of piezoelectric crystals that produce ultrasound waves when stimulated by an electrical current. These ultrasound waves propagate through the different tissues and are reflected back to the transducer when they encounter an interface of tissues with different acoustic impedances. Once they are reflected back to the transducer, they stimulate the piezoelectric crystals, and these in turn produce an electrical current that is proportional to the intensity of the reflected ultrasound wave. The time needed for the ultrasound waves to come back to the transducer is interpreted as the depth of the tissue reflectors. Depending on the intensity of the reflected waves, grayscale pixels will be represented on the screen, ranging from anechoic (black) to hyperechoic (white) (**Figure 35.1**).

In ultrasound imaging, the depth of the tissues that can be imaged is given by the wavelength of the waves emitted by the transducer, whereas the resolution (ability to discriminate between two points) of the image is given by the frequency. A larger wavelength results in a larger depth of field, and a higher frequency results in an increased resolution. Unfortunately, frequency and wavelength are inversely proportional to each other, so ultrasound imaging is a constant negotiation of image resolution (frequency) versus depth of field (wavelength).

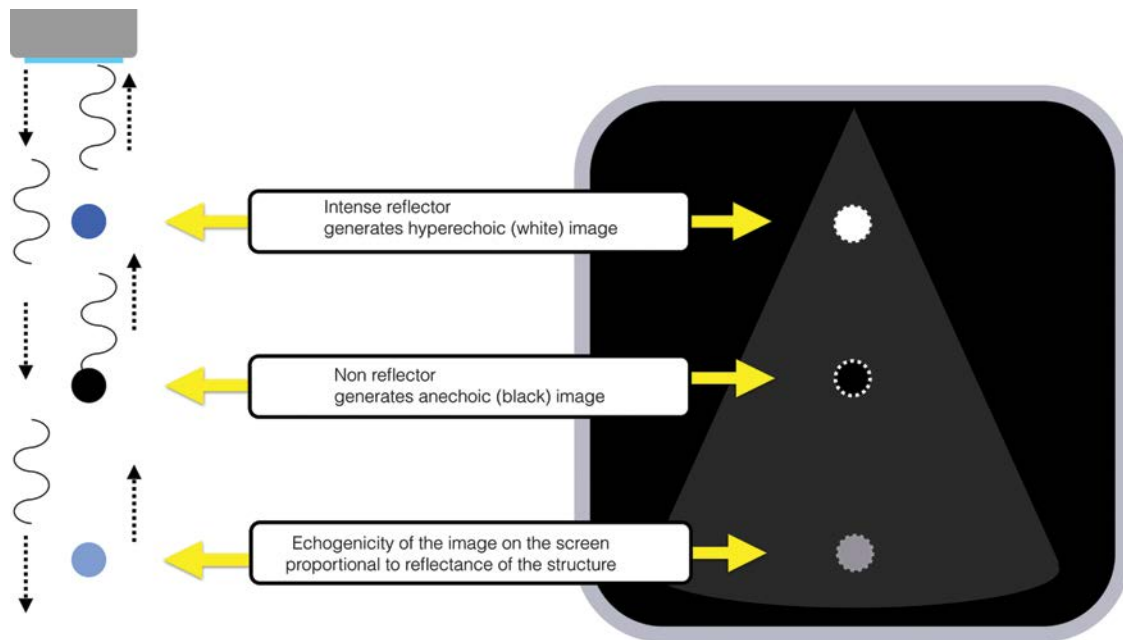


Figure 35.1 Principles of ultrasound imaging. The probe emits ultrasound waves, which are reflected at interphases of tissues with different acoustic impedances. The probe then receives the returning echoes and generates images on the screen that are proportional to the intensity of the reflected echoes.

Certain tissues, such as bone and lung, are not ideal for ultrasound imaging, due to their high reflective or scattering properties. This is a major limitation for transthoracic echocardiography, because adequate imaging of the heart through the chest wall requires circumventing the “obstacles” imposed by the ribs and lungs.

TEE consists of a small transducer that can be introduced inside the esophagus. This transducer takes advantage of the position of the esophagus immediately behind the left atrium to produce high-quality images of the heart, without the significant imaging problems produced by bone and lung that occur with transthoracic echocardiography.³

THREE-DIMENSIONAL TEE

Evolution of three-dimensional echocardiography

The initial attempts at 3D ultrasound imaging started in the 1960s as an attempt to reconstruct the anatomy of the human orbit, but it was not until the mid-1970s when 3D TEE was described. The first 3D TEE systems produced 3D images by aligning and reconstructing a sequence of two-dimensional (2D) images obtained by a mechanically driven transducer.⁴ These systems had significant limitations, such as large transducer sizes and low processing speeds, among others. The reconstruction of a complete data set mandated significant computer processing capabilities and also required significant time (between 1 and 5 minutes).

In the 1990s, significant technological developments allowed miniaturization of transducer components and increased computational power. This favored the design of 3D TEE probes with a matrix arrangement of a large number of active elements. These probes are able to obtain real-time and high-quality 3D volumetric data without the need for offline reconstruction (**Figure 35.2**).

Matrix probes are also capable of performing reconstructions, where multiple adjacent 3D volumes (slices) are captured and then “stitched” together, resulting in a large sector being interrogated with a high temporal resolution. This

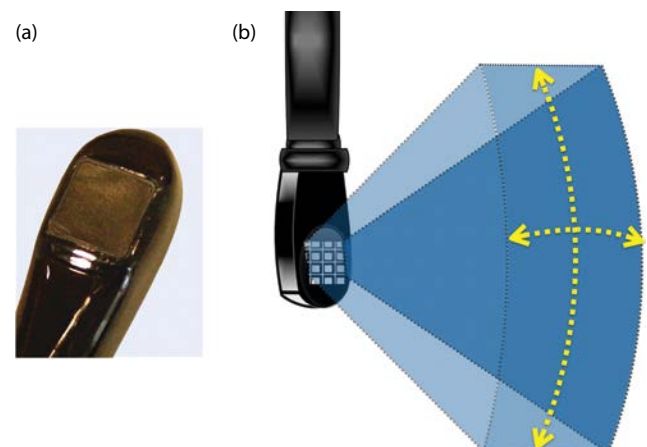


Figure 35.2 (a) The tip of a 3D TEE matrix probe. (b) The matrix array of crystals in the probe allows real-time 3D imaging.

imaging mode is known as R-wave gated imaging because of its use of the R wave in the electrocardiogram to synchronize and join the different slices.

How are three-dimensional TEE images obtained?

Obtaining a 3D TEE image is a complex process that encompasses data acquisition, storage, processing, and display. Similar to 2D TEE, 3D TEE imaging is initiated when the active elements in the matrix array probe emit and then receive ultrasound pulses. However, in contrast to 2D TEE, a 3D TEE machine's computer transforms the scanned raw data (i.e., the returning pulses) into a 3D data set that is composed of small cubes, or voxels (volume of pixels). These voxels are then placed into a Cartesian volume by assigning each of them x - y - z coordinates and an echo-intensity value.

After the voxels are assigned their respective coordinates and echo-intensity, a process called *interpolation* fills the gaps between all data points with voxels of similar characteristics.

The interpolated data set is then rendered to display the depth of the 3D image in a flat 2D screen, so the echocardiographer can adequately visualize it. One of the most common rendering methods in 3D TEE is volume rendering, which displays a 3D object with a detailed surface and inner structure. Volume rendering is accomplished by selectively colorizing and opacifying different regions of the image, as well as shading and smoothing.

For R-wave gated imaging, an additional process called *concatenation* is necessary. During concatenation, each slice is aligned both spatially and temporally. Adequate spatial alignment requires the probe and the patient to stay as motionless as possible. This is accomplished in the operating room by briefly pausing mechanical ventilation and avoiding motion during the acquisition of the image. Temporal alignment organizes the data according to the electrocardiogram, so that every slice is synchronized and the 3D volume can be visualized uniformly during systole and diastole. Hence, cardiac arrhythmias may significantly interfere with temporal alignment during R-wave gated imaging.

Multiplanar reformatting

Besides the “pretty pictures” that 3D TEE provides, one of its most useful applications is multiplanar reformatting. This mode allows the operator to slice and present the 3D data set as different planar views (Figure 35.3). Orthogonal alignment of these views can help increase the accuracy of measurements, which has demonstrated to be beneficial in several clinical situations, such as calculation of aortic valve area, determination of cardiac output, and mitral valve analysis.⁵⁻⁷

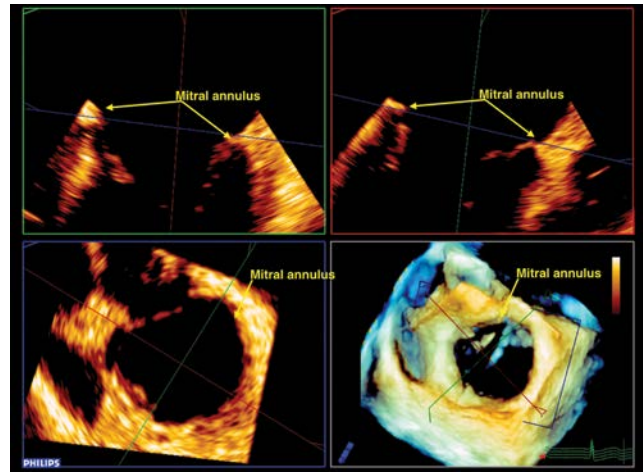


Figure 35.3 A 3D acquisition of the mitral annulus.

Through multiplanar reformatting, the 3D data can be manipulated and sliced into orthogonal planes to aid in visualization and measurement of the structure of interest.

THREE-DIMENSIONAL TEE IN MINIMALLY INVASIVE SURGERY AND INTERVENTIONAL CARDIAC PROCEDURES

Continuing development in minimally invasive and interventional cardiac procedures has increased the need for improved imaging modalities for procedural guidance. Traditionally, guidance for these procedures has been performed with fluoroscopy, which is limited by the need for intravenous contrast and radiation exposure.^{8,9} The main advantages of TEE over other imaging modalities are its portability and its capacity to provide real-time information.¹⁰

Several minimally invasive and interventional cardiac procedures benefit from 3D TEE for preoperative assessment, surgical planning, procedural guidance, and evaluation of surgical results. We briefly discuss some of the procedures that benefit from 3D TEE guidance.

Three-dimensional TEE for percutaneous closure of atrial and ventricular septal defects

Percutaneous closure of secundum-type atrial septal defects results in a decrease in perioperative complications, reduced length of stay, and reduced survival benefit when compared to surgical closure.^{11,12} 3D TEE examination allows for confirmation of the defect and evaluation of its irregular shape. It also permits confirmation of adequate percutaneous closure device positioning prior to deployment (Figure 35.4a).

The morbidity and mortality of acquired ventricular septal defects after myocardial infarction can be reduced with percutaneous closure. 3D TEE is particularly useful for delineating the complex anatomy of the defect and its

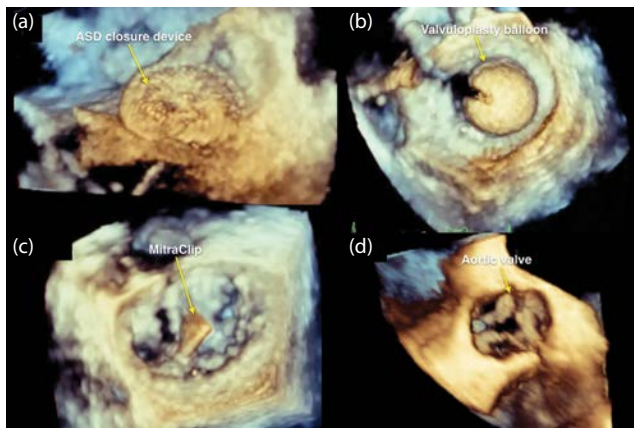


Figure 35.4 (a) An adequately positioned atrial septal defect closure device is visualized from the left atrial perspective. (b) An inflated mitral valvuloplasty balloon is seen from the left atrial perspective. (c) A MitraClip is in adequate position, grasping the mitral valve leaflet borders to improve coaptation. (d) A calcified aortic valve is seen in a patient with severe aortic stenosis.

relationship to other cardiac structures (e.g., mitral and tricuspid valve). Similar to atrial septal defects, 3D TEE allows confirmation of the closure device's position prior to deployment.

Three-dimensional TEE for percutaneous coronary sinus catheter placement

Cardioplegia delivery through the coronary sinus (i.e., retrograde cardioplegia) is an important component of a large majority of minimally invasive and robotic cardiac surgeries.

During these surgeries, a retrograde cardioplegia catheter is introduced through the internal jugular vein and advanced inside the right atrium. Afterward, real-time 3D TEE guidance can be used to cannulate the coronary sinus under direct visualization.

Three-dimensional TEE for percutaneous valve interventions

The left atrium is the most difficult cardiac chamber to access percutaneously. Interatrial septal puncture permits access to the left atrium through the systemic venous circulation. It is commonly performed during percutaneous mitral valve procedures, such as balloon valvuloplasty for mitral stenosis and MitraClip (Abbott Laboratories, Illinois) placement for mitral regurgitation. In addition to enhancing the view of the interatrial septum during puncture, 3D TEE guidance can be used for accessing the mitral valve with the catheter-mounted devices. Guidance with 3D TEE may be useful during valvuloplasty balloon

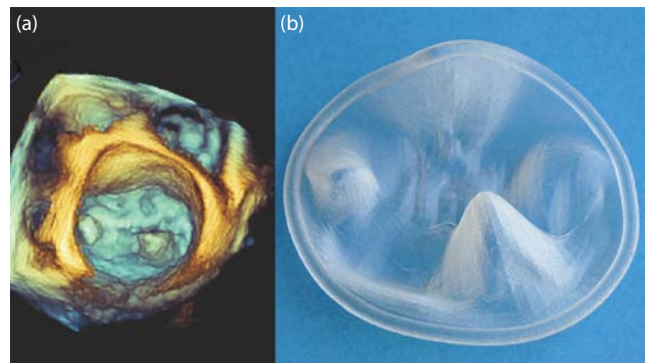


Figure 35.5 (a) A 3D TEE of a patient with a prolapsed segment of the posterior mitral leaflet. (b) Using the Cartesian data obtained from the 3D echocardiogram, the patient's valve can be 3D printed.

inflation (**Figure 35.4b**), and it is particularly useful to deploy and confirm adequate positioning of the MitraClip (**Figure 35.4c**).

In transcatheter aortic valve implantation, 3D TEE has an important role in assessing the anatomy of the left ventricular outflow tract and the ascending aorta, prosthesis sizing, and determination of adequate positioning (**Figure 35.4d**).¹³

FUTURE DIRECTIONS

The role of 3D TEE in minimally invasive and interventional procedures will most likely continue to expand in the future. One particularly promising future application of 3D TEE is 3D printing of cardiac structures.

3D printing technology is based on stereolithography, where layers of a material are stacked in succession to form a 3D structure, 3D printing holds promise for numerous applications in medicine.¹⁴ Recently, 3D printing using echocardiographic data has been described.^{15,16} Cartesian coordinates derived from 3D TEE data can be exported from the 3D analysis software and imported into 3D modeling software. A printable 3D file can then be obtained, which can be printed using a commercially available 3D printer.¹⁷ This process can be performed in a fairly reasonable time, making intraoperative data capture and printing feasible.

Although still in the initial stages of development, 3D printing of cardiac structures using 3D TEE data holds great promise for a diversity of applications, from education (i.e., task training) to manufacturing patient-specific prosthetic materials (**Figure 35.5**). This technology can be used to create realistic, patient-specific models, which may be superior to visualization of 2D and 3D images on a computer monitor.

Despite the exciting possibilities for this technology, 3D printing of TEE-derived data has some limitations. Further research is needed in order to create more user-friendly

processes, faster printers that can be used immediately in the operating room, and biocompatible materials with real tissue characteristics that can be implanted.

CONCLUSION

3D TEE is increasingly being used to complement conventional imaging during minimally invasive cardiac surgery and interventional cardiac procedures. Technological advancements in this field have made real-time 3D imaging possible, increasing the role of TEE in procedural guidance.

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The impact of skills warm-up in minimally invasive surgery

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INTRODUCTION

A pre-event warm-up is a concept that has been applied across many disciplines, varying from athletes to performance artists. It would seem reasonable to consider the applicability of this concept to the field of surgery. Surgery requires proficiency in physical attributes such as fine motor skills and endurance, as well as in mental attributes such as concentration and focus. Performance enhancement via pre-event warm-up could have major applicability for minimally invasive surgery. The benefits of a warm-up, both mental and physical, are well known and include more efficient movements, reduction in overall task time, and improved outcomes. In addition, reduced anxiety and improved cognitive function are highly regarded by-products of this activity (Figure 36.1).¹

Some of the direct physiological benefits of warm-up include release of adrenaline, which leads to increased heart rate and dilation of capillaries. This enhances distal blood and oxygen delivery to critical tissues, which maximizes

performance.² A warm-up regimen also causes an increase in the temperature of muscles, along with an acceleration of blood flow, and enhancement of lactic acid removal. This promotes enzyme activity, facilitates the release of oxygen from hemoglobin, and enhances the extensibility and elasticity of muscle fibers.³ It has been suggested that increased muscle fiber elasticity increases the force and speed of contraction, which can also augment the efficiency of performing tasks.² Furthermore, warming-up leads to increases in speed of nerve impulse conduction. This is an important asset for performance of any activity including laparoscopic tasks.² A 1994 study by Smith concluded that physiologic warming-up led to increased muscle/tendon suppleness, stimulated blood flow to the periphery, increased body temperature, and enhanced free, coordinated movement.⁴ All of these factors have the potential to promote enhanced execution of procedures and help secure superior outcomes.

In addition to these physiologic benefits, cognitive benefits have also been noted. A pretask mental warm-up has been shown to reduce anxiety related to the task performance, which in turn allows for clearer thinking, and less sympathetic overactivation. Mental warm-ups may also invoke the same motor circuits in the brain that will be subsequently used to complete the task at hand; this could allow for more efficient nerve conduction and improved coordination during task execution.¹ In addition, the process of mentally thinking out the task prior to execution has been noted to improve focus and increase preparedness when performing the task itself.⁵ Mental imagery may be combined with relaxation techniques to further improve performance through stress reduction and increased receptiveness to mental warm-up.⁶ These beneficial factors can easily be applied to minimally invasive surgery and potentially improve task performance and lead to better overall outcomes.



Figure 36.1 Video game warm-up by surgeon before minimally invasive surgical procedure.

The approach to preoperative warm-ups does not subscribe to a one-size-fits-all philosophy. There are different processes and programs that fall into distinguishable categories, which prepares a surgeon to perform with flawless execution. This chapter gives an overview of the use of these cited in the literature.

MENTAL WARM-UPS

Many experts believe that the process of visualizing the performance of an action in one's mind prior to its execution may improve the achievement of that action. Mental warm-up is defined as the "cognitive rehearsal of a task in the absence of physical movement," and it has been utilized in multiple venues such as dance, sports, and public speaking.⁵ Sanders et al. was one of the first groups to evaluate mental imagery rehearsal in relation to surgical skills. In 2004, he used a group of medical students to assess the effect of mental rehearsal on suturing on pig's feet and surgical tasks performed on a live rabbit. Though the exact process was not mentioned, the group found that performance after a mental warm-up was equivalent to physical practice.^{7,8}

Immenroth and his group assessed mental warm-up in regard to laparoscopic cholecystectomies performed on the Pelvi-Trainer simulator (Ethicon Endo-Surgery, Cincinnati, Ohio). His technique consisted of asking surgeons to mentally envision an "operation primer" prior to the surgical simulation, with the assistance of a mental trainer. This primer consisted of the detailed surgical procedure broken down into a set of structured points. He demonstrated that mental training optimized the performance of surgeons and led to better outcomes overall.⁹

Arora et al. performed a more systematic evaluation of mental warm-up with regard to virtual laparoscopic cholecystectomies in 2011. Their method consisted of participants reviewing a mental practice script that described the surgical procedure in great detail for 30 minutes prior to the task. They demonstrated that mental practice and visualization led to improved performance and learning curves of residents who were performing simulated laparoscopic cholecystectomies, but they did not improve technical skill.⁵

Overall, mental training seems to be especially beneficial in establishing task-specific checklists to ensure a surgeon does not miss any crucial steps.⁹ They essentially cost nothing to employ and need no special equipment to complete. However, they do require significantly longer warm-up times and do not seem to be an effective means for improving dexterity or technical skills.

COMPUTER-BASED SIMULATIONS

Virtual simulators are a rapidly growing part of a surgeon's training in procedures of all surgical subspecialties. There are also extremely wide ranges of virtual reality simulators including devices that simulate an actual operation using

similar instruments and devices that build competency of basic skills such as hand-eye coordination using a variety of tasks in the open and minimally invasive surgical environment. Many simulators are even designed with game interfaces to captivate the user and make practicing more enjoyable. With the surge of simulators in surgical training, and their incorporation into the surgery culture, there is a growing body of research looking into if these simulators have an additional benefit in being used for preprocedural warm-up.

In 2006, using a small laparoscopic trainer, 12 medical students and 12 ob-gyn residents were asked to transfer 30 tablets with a 5 mm grasper from one point to another. The first trial was considered the warm-up task and reflected a baseline measurement. They then repeated this exercise after a 5-minute break. Both groups showed an improvement of 25%–29% between the initial warm-up time and the subsequent task time.¹⁰ In 2009, Kahol et al. built off of this study and demonstrated that a simple 15-minute warm-up using a virtual simulator improved time performance of a laparoscopic ring transfer task; this held true even if the measured tasks did not relate to the warm-up tasks. This study also measured the effects of warm-up on fatigued and sleep-deprived physicians. Warm-up was shown to significantly improve performance for this group of surgeons.¹ The following year, a small study looked at residents using a laparoscopic simulator as a warm-up prior to performing a laparoscopic cholecystectomy in the operating room. When residents utilized the simulated warm-up activity, they performed significantly better during the procedure, as measured by the validated Objective Structured Assessment of Technical Skills global rating scale.¹¹ This study determined that there is a direct crossover between simulations and skill transference to the actual operating room.¹² Similarly, another study done in 2012 with ob-gyn residents demonstrated that warm-up exercises on a laparoscopic trainer (including bead transfer and "run the rope") resulted in improved performance (measured using three validated global rating scales) in the operating room.¹³ In the same year, Lee and his group demonstrated that completion of a simulated electrocautery task warm-up along with a laparoscopic knot tying warm-up resulted in improved cognitive and psychomotor performance during laparoscopic renal surgery. Performance was measured based on electroencephalography, pupillary eye tracking, hand motion, and postural recordings.¹⁴

With the emergence of robotic surgery, there are now increasing amounts of robotic simulators as well. A large study using general surgeons, gynecologic surgeons, and urologists compared a 3- to 5-minute robotic simulator warm-up versus reading about the required task for 10 minutes. Those who performed the short tactile warm-up had a faster completion time, made less errors, and performed at an overall higher level than those who read prior to the robotic task. The more established surgeons tended to have the highest increase in performance following the robotic simulation (Figure 36.2).¹⁵

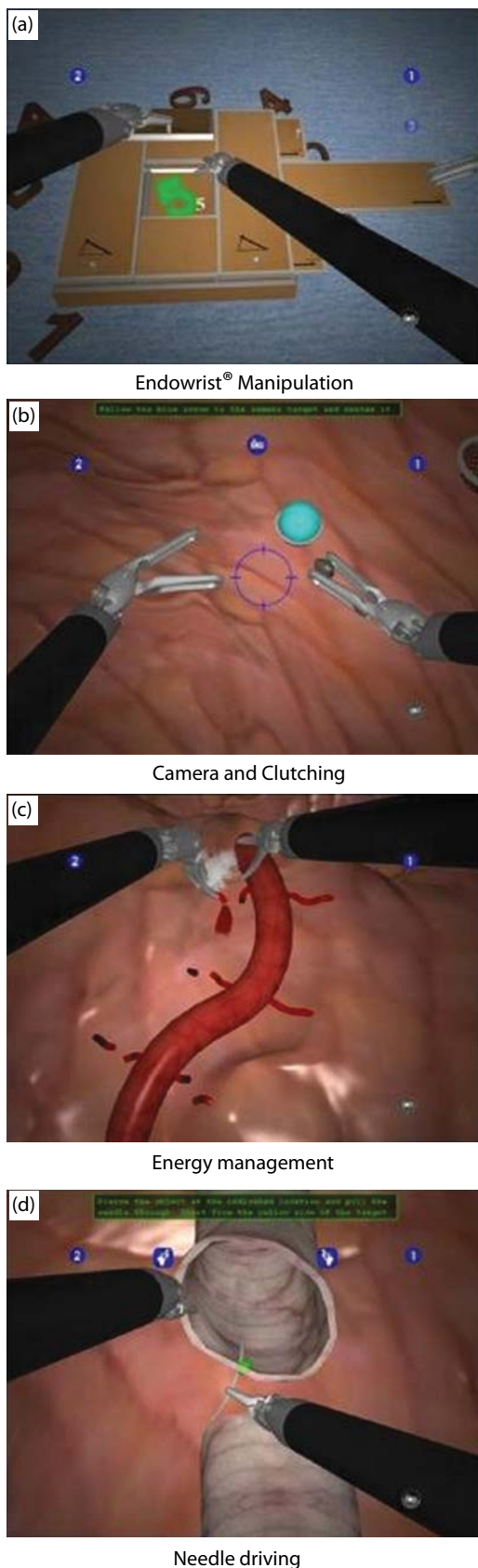


Figure 36.2 Robot warm-up tasks.

In 2015, another study demonstrated the value of simulated preoperative warm-ups for surgical residents. Residents who spent 10 minutes in the simulation lab prior to surgery performing laparoscopic tasks, such as peg transfer, Endoloop placement, pattern cutting, and extracorporeal and intracorporeal suturing, had significantly better efficiency of movements, depth perception, and bimanual dexterity, as evaluated better by their attendings.¹⁶

While simulators have proven to be effective at training and as a warm-up device, they do have many shortcomings. Most simulations are expensive and in short supply in hospital systems. Many hospitals do not have enough simulations to be effectively utilized by residents to learn from, let alone for warm-up use; many places cannot even afford to own a simulator. Furthermore, many simulators require significant space or time to set up and are located in an inconvenient place for use as preoperative warm-up. In addition, the haptic feedback system used by most simulators to allow the surgeon to “feel” the virtual tissue has been criticized for lacking realism.¹⁷

VIDEO GAMES

In 2007, Rosser and his team opened the door to video game use in surgical training by demonstrating the positive correlation between video game skill, quantified by performance on three video games, and laparoscopic skill and suturing ability: *Super Monkey Ball* (trademark of SEGA 2001 for Nintendo GameCube), *Silent Scope* (trademark of Konami 1999 for PlayStation 2), and *Star Wars: Racer Revenge* (trademark of LucasArts Entertainment 2002 for PlayStation 2). This was measured using the surgeons’ scores from the *Top Gun* training program.¹⁸

Video games have been evaluated as a preoperative warm-up as early as 2008, when Sadandanan and his team demonstrated that playing the game *Super Monkey Ball* for 10 minutes resulted in improved times of completion for a subsequent laparoscopic skills task. They explained this improvement by noting that the skills used in video games, such as hand-eye coordination, depth perception, and ambidexterity, are also used while performing laparoscopic tasks.¹⁹ Since then, the use of video games as a preoperative warm-up has been further investigated. In 2011, Plerhoples and his group performed a similar investigation using the *Super Monkey Ball 2* game for the mobile device. This study revealed that those who performed the 10-minute preoperative warm-up had significantly less errors while performing a laparoscopic task, compared to those who did not have any warm-up. When extrapolated to the operating room, a reduction in task error may correlate to a decrease in surgical errors.²⁰

Rosser and his team performed one of the most in-depth studies to date involving the use of video games as warm-up for laparoscopic tasks in 2012. This study evaluated the use of three different video games and their effects on scores during the *Top Gun* Training program. The results



Figure 36.3 Underground hand controllers.

demonstrated better overall performance in the group that used video games as a preoperative warm-up. Furthermore, the video game warm-up group completed the suturing drill with fewer errors overall. It also showed that as little as 6 minutes of warm-up could positively impact performance.²

In addition to using preexisting games for preoperative warm-up, one study used a game that was specially designed for laparoscopic surgery. This game, called *Underground* (Cutting Edge, Leeuwarden, Netherlands), involves specially designed controls that mimic the actual hand instruments used during laparoscopic surgery. A recent study demonstrated that warm-up with this game correlated with a significant reduction in time to perform laparoscopic skills tasks (Figure 36.3).²¹

The advantage of using video games as preprocedural warm-up platforms includes cost effectiveness, easy accessibility, and the engagement of both motor and cognitive functioning. Video games are fun, cognitively engaging, and increase focus and attention/concentration. Also with the aura of ever-present competition, it results in elevated time on task. Imagine a day when training is never boring and you want to play/train all day (Figure 36.4).



Figure 36.4 World's first video game warm-up suite.

DISCUSSION

In the United States with the advent of the Affordable Care Act, quality, good outcomes and excellent patient satisfaction have begun to dominate the landscape of surgical care. All validated processes or programs that enhance performance will be aggressively considered. With decrease in hospital stay, less pain, faster return to work, fewer wound infections, and fewer postoperative hernias, minimally invasive surgery fulfills an excellent value-based profile that will be the hallmark for the future of surgery around the world. Today, there is a more intense focus on expanded adoption of minimally invasive procedures, and organized efforts such as the Society of American Gastrointestinal and Endoscopic Surgeons GetWellSooner program are leading the way. GetWellSooner is intended to improve the value of patient care by promoting the adoption of and access to minimally invasive surgical techniques. Development of organized efforts such as this will greatly assist in increasing the adoption rates of advanced procedures. Subsequently, preprocedural warm-up will no doubt play an increasing role.

We have in this chapter reviewed the rationale and investigative findings of all of the categories of preprocedural warm-up. It should be stressed that the take-aways should be that “they are effective” and “one size does not fit all.” Mental warm-ups, computer-based simulations, and video games all have a role to play in an effective warm-up routine. But one category may not be sufficient to establish maximum readiness. For instance, mental readiness may be more effectively teamed with clinical computer-based simulations to advance procedural competence. And basic skills establishment and maintenance may be better served by using a blend of nonclinical procedural simulators, tabletop trainers, and video games.

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The role of mental training in minimally invasive surgery

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INTRODUCTION

Skills acquisition is an important aspect of training in surgery residency programs and has typically been taught by an apprenticeship model. A trainee observes an experienced surgeon performing a procedure. The teaching surgeon verbalizes and explains to the surgical trainee how to perform different maneuvers and surgical techniques in order to successfully perform an operation. It is expected that in a reasonable period of time, the surgical trainee, via repeat observation, will develop the necessary skills to independently conduct a procedure.¹ All surgical procedures, including those performed via laparoscopic or robotic approach, require knowledge of sequence of events, honed surgical skills, fine motor skills, and hand-eye coordination.² Over the past decade, the surgical training model has changed. Restricted duty hours have limited residents to repeated exposure in the operating room—decreasing their observation time. In addition, the introduction of optoelectronic instrumentation has resulted in increased surgical technical complexity—this is mainly as a result of lack of three-dimensional visibility, counterintuitive instruments, and loss of haptic feedback.^{1,3}

Simulation-based training is a validated teaching alternative that has been accepted as an adjunct training model to patient-based training. It has shown that it allows participants to develop skills by repeated attendance and practice, and that these skills can be transferred to the operating room.^{4,5} In addition, skills acquisition with simulation has shown to reduce operative time and expedite development of surgical skills.⁶ Despite these positives, simulation-based training has not been popularized and transferred to practice mainly due to limitation of faculty time, lack of designated space, and equipment cost.⁷

In order to acquire motor skills, Fitts and Posner reported that the following three stages must occur: (1) a *cognitive state* in which the apprentice understands what needs to be done, (2) an *associate state* that consists of attempting ways to accomplish the task, and (3) an *autonomous stage* where the steps to accomplish the task become autonomous after repetitive training.^{8,9}

The known definition of *mental practice* was first introduced by Richardson as “the symbolic rehearsal of a physical activity in the absence of any gross muscular movements.”^{10,11} Some recommend adding physical movements to enhance the effects of mental practice.¹² Motor imagery is based on kinesthetic and visual imagery by the participant.¹³ Also, when participants observe someone else performing the physical movement of a task, participants activate the corresponding somatosensory areas.¹⁴ This preparation method is well documented in the musician and sports literature.^{10,15} **Figures 37.1 and 37.2** represent the nodal points used by professional athletes in hammer throwing and hurdling.

Vaeley and Walter¹⁶ described two theories of how mental practice impacts acquisition of technical skills. The psychoneuromuscular theory states that mental practice strengthens muscle memory by having muscle fire in the correct movement sequence without executing the movement. The second theory states that mental practice produces mental blueprints for movement patterns, and rehearsal of these blueprints allows movements to become familiar and automatic.¹⁶

The sport theory has five areas of imagery: a motivational specific imagery that refers to goal settings, a motivational general mastery that consists of coping and mastering challenging situations; the motivational general arousal feelings required to develop effective imagery; a cognitive specific



Figure 37.1 Mental training nodal points used in hammer throwing.



Figure 37.2 Mental training nodal points for hurdling used by an athlete of the German National Team.

area that relates to imaging a specific skill needed to perform a task, which has shown to be the most efficient type of imagery; and the cognitive general area that is the thought that links the specific motor skills.^{17,18}

Mental practice is a method commonly used and known to enhance physical performance in other highly skilled motor industries, such as sports and music.^{10,15} Weinberg et al. reported that mental training imagery is a skill that can be taught, learned, and improved with training.¹⁹ Literature supports that mental practice not only enhances end-performance, but also in some circumstances it can be more effective than physical practice.¹⁰ Although physical practice is indeed imperative in order to acquire physical skills, mental practice can considerably enhance physical proficiency.²⁰

Eberspächer and collaborators²¹ described the following four sessions of mental training:

1. *External observative training*: the trainee observes a model while performing the movement to be learned.
2. *Subvocal training*: the trainee calls up a clear visual image of the movement through external or internal self-talk.

3. *Internal observative training*: the trainee visualizes himself or herself or another person from the outer perspective performing the movement he or she wants to practice.
4. *Ideomotoric training*: the trainee visualizes himself or herself executing the movement and at the same time tries to feel and perceive as many sensory aspects of the process and environment as possible.

There are known sensory modalities that enrich the subject's imagery experience and enhance the task performance by facilitating a more accurate mental representation of the skill to be developed; these modalities are: visual (seeing oneself performing the procedure), cognitive (thoughts needed to perform the task), and kinesthetic cues (feeling of executing an action).

MENTAL PRACTICE EVIDENCE

The first research regarding mental practice was published by Jacobsen.²² Using electromyography, he observed muscle electrical activity on patients that imagined bending their arms or lifting weight. Performers who utilize mental practice as a tool to practice a skill have been shown to improve performance by at least half a standard deviation below the control group.²³

Mental practice has been shown to be beneficial in both participants in their early stages of learning and those with prior experience in the tasks.^{24,25} Also, it has been reported to be effective mainly on tasks with cognitive elements, although it also is effective on physical tasks.¹⁰

The retention interval in mental practice is the interval between the last mental practice and actual performance. The strongest mental effect is when the retention interval is the shortest (Day 0 or immediately following mental practice), although the effects of mental practice reduced by 50% at a retention interval of 14 days and the lowest effect were seen at 21 days, with some researchers having reported efficacy up to 28 days.^{10,24,26,27} Mental practice is most efficient with an overall practice time of approximately 20 minutes.¹⁰

Driskell and collaborators¹⁰ reported that in order for mental imagery to be effective, the participant must first be familiar with the tasks prior to the imaginary session. Other studies have shown that mental practice can be as effective as physical practice to learn a motor skill, because mental practice activates the same neural areas as the physical activity.^{13,28-30}

Roth and collaborators³¹ used functional magnetic resonance imaging (MRI) signals to measure brain activity in normal right-handed subjects during actual and mental execution of a finger-to-thumb opposition task. They found a significant involvement of the contralateral primary motor cortex (M1) of 30% during task execution, and during imagery there was bilateral activity of the premotor cortex and rostral part of the posterior supplementary motor area. The authors concluded that the findings support the hypothesis that motor imagery involves virtually all stages of motor control.

Using positron emission tomography (PET), Mellet and collaborators³² showed that mental imagery shares neural networks with major cognitive functions such as language, memory, and movement depending on the nature of the imagery task. The activated areas included the premotor and motor areas (premotor cortex, supplementary motor area, and primary motor cortex), subcortical areas of the cerebellum, and the basal ganglia^{33–35}

Honda and collaborators³⁶ also used positron emission tomography to measure regional cerebral blood flow, and they found that during explicit learning (correct recall of the test sequence), there was increased activity of the posterior parietal cortex, precuneus, bilateral premotor cortex, and supplementary motor area. During implicit learning (when subjects were not aware of the sequence), there was increased activity in the contralateral primary sensorimotor cortex (SM1). The authors concluded that during different motor sequence learning different cortical regions are dynamically involved.

EVIDENCE IN SURGICAL TRAINING

Many surgeons report that on a routine basis they mentally review the cases before a surgery, both on a general and specific cognitive level, and specifically focus on the technically difficult steps of the case. This helps in the development of motor skills,¹⁷ and in surgical residents it helps to increase emotional preparedness allowing them to perform better in stressful situations.¹⁷

Surgeons perform and develop fine-motor movements in a stressful environment, like professional athletes and musicians.^{10,15} Even though mental practice has been studied broadly in professional athletes, only a few studies have been performed applying this training approach in laparoscopic simulator training and have shown an improvement in laparoscopic performance.^{1,37,38}

Sanders and collaborators³⁹ studied the effectiveness of the combination of mental imagery and physical practice in medical students. After a lecture and teaching of basic surgical skills, 65 second-year students were randomly assigned to one of three groups. The first group had three sessions of physical practice, the second group had two sessions, and both the first and second groups had one mental imagery session. The third group had one physical practice session and two mental imagery sessions. The authors concluded that mental imagery combined with physical practice might be economically beneficial in surgical skills training and statistically equivalent to additional physical practice.

In another study, Bathalon and collaborators¹² assessed 44 medical students in learning emergent cricothyrotomy. The students were randomly assigned to one of three groups. The first group incorporated training use of mental imagery with physical movements known as kinesiology, the second group used only kinesiology, and the third group was a control group that used the standard training method using a

mannequin. The conclusion was that mental imagery with physical movements resulted in an improvement in acquisition and performance of an emergency procedure.

Arora and collaborators⁴⁰ developed a mental practice script with key visual, cognitive, and kinesthetic cues for laparoscopic cholecystectomy. Each subject was asked to mentally rehearse the steps within 30 minutes. In the study, 10 subjects were experienced surgeons who had performed more than 100 laparoscopic cholecystectomies, and 10 subjects were novice surgeons with less than 10 laparoscopic cholecystectomy cases. Significant global imagery improvement was noticed in both groups, validating mental practice as an acceptable training approach.

In a follow-up study, Arora and collaborators¹ assessed 20 novice surgeons who performed a virtual reality cholecystectomy. All participants underwent 1 day of introduction to laparoscopic surgery, instruments, and common problems. This was followed by training with a laparoscopic simulator. All participants performed daily simulated laparoscopic cholecystectomies for 5 days. The mental training group received 30 minutes of intervention prior to each procedure. The mental training group had a flatter learning curve and better performance than the control group.

Immenroth and collaborators³⁸ also assessed the role of mental training in laparoscopic cholecystectomy. In this study, 98 surgeons were randomized to additional mental training, practical training, or no additional training. The authors concluded that additional mental training was an effective way to optimize outcomes and was associated with fewer costs.

Mulla and collaborators⁴¹ published their findings of a randomized controlled trial comparing a training box, virtual reality, and mental training in developing minimally invasive surgical skills. They divided the participants into five groups: a control group without training, box trained group, box trained with additional practice sessions, virtual reality trained group, and mental trained group. They reported that the skills learned on a box trainer can also transfer into the virtual reality trainer, although the skills learned via virtual reality are not transferable to the box trainer. Also, while there was no difference in the mental group, it is important to note that this group did not receive mentoring during the physical training sessions, whereas for the box trainer and simulation training groups, there was a mentor for feedback.

Louridas and collaborators⁴² randomized 20 surgical trainees to either a conventional training or mental practice group trained by a performance psychologist. Their surgical skills were measured by a porcine laparoscopic jejunojejunostomy. They reported that during the crisis scenario, 70% of the mental training group improved their performance, whereas 40% of the control group deteriorated. Also, mental imagery improved significantly after mental practice in this group. The authors concluded that mental practice improves technical performance in advanced laparoscopic tasks in the simulated operating room, and allows trainees to maintain or improve their performances despite stress.

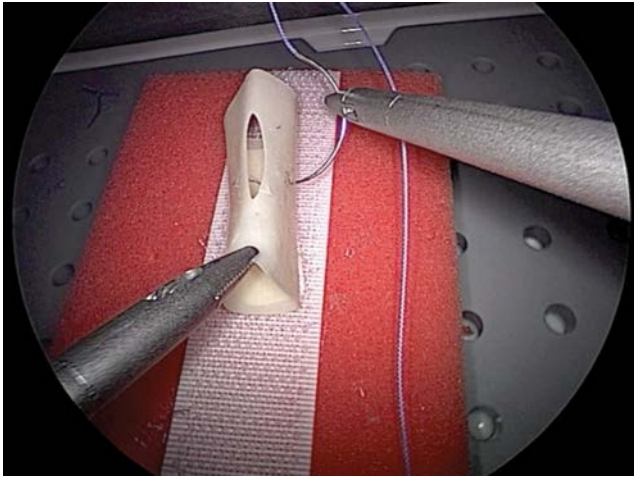


Figure 37.3 Fundamentals in Laparoscopic Surgery (FLS) rubber tube model used to tie laparoscopic surgical knots.

Eldred-Evans and collaborators⁴³ assessed the use of mental training in developing basic laparoscopic skills. Sixty-four medical students were randomized to one of four groups. The first three groups were trained to cut a circle on a box trainer; the first group did not have additional interventions, the second had additional virtual reality training, and the third had additional mental training. The fourth group had both virtual reality training and mental training. The box trainer group with mental practice demonstrated improvement in laparoscopic skills. The conclusion was that addition of mental training led to improvement in laparoscopic skill development, and that this approach has the potential to challenge virtual reality as a cost-effective training method.

Our group⁴⁴ recently performed a project entitled “Outcomes of Surgical Skill Training After a Systematic Approach Utilizing a Laparoscopic Suturing Platform.” In this project, we prospectively studied 18 surgery residents. The task assigned consisted in tying two laparoscopic knots on a Fundamentals in Laparoscopic Surgery (FLS) rubber tube (Figure 37.3). First, a baseline measurement of all residents was obtained. This was followed by an experienced surgeon explaining the laparoscopic surgical

knot-tying technique (LKTT). At this point, participants were randomly assigned to either a control (CG) or systematic approach group (SAG). The SAG was handed the nodal points for laparoscopic surgical knot tying. Follow-up measurements were performed in 3 weeks.

There were four females (control: 2 [22.2%] versus SAG: 2 [22.2%]; $p = 1.0$) and 14 males (control: 7 [77.8%] versus SAG: 7 [77.8%]; $p = 1.0$). There were seven postgraduate-year (PGY) 1 (control: 3 [33.3%] versus SAG: 4 [44.4%]), five PGY 2 (control: 3 [33.3%] versus SAG: 2 [22.2%]), PGY 3 (control: 2 [22.2%] versus SAG: 2 [22.2%]) and three PGY 4 (control: 2 [22.2%] versus SAG: 1 [11.1%], $p = 0.48$). Seventeen residents were right-handed (control: 8 [88.8%] versus SAG: group 9 [100%]; $p = 0.47$). In the control group, three (33.3%) and five (55.6%) in the SAG group had previous surgical training ($p = 0.637$). Two (22.3%) and four (44.4%) from the control and SAG, respectively, had undergone laparoscopic training ($p = 0.63$). There was no difference in interest for video games ($p = 0.289$), for billiard ($p = 0.485$), and for minimally invasive surgery ($p = 0.89$).

On Day 0, a baseline measurement was performed, followed by an explanation of LKTT and then a second measurement. All residents received a LKTT teaching video. Only the SAG received the nodal points for the assigned task. At 3 weeks, a follow-up suturing session was recorded. The analysis was undertaken at different periods comparing the performance between groups. Initially, we did not find differences between the groups (Table 37.1), although at follow-up the SAG was faster (2.4 ± 0.44 versus 4.0 ± 1.08 minutes; $p = 0.03$) (Table 37.2). No differences were seen in the CG from baseline and follow-up (Table 37.3).

On Day 0, between baseline and after LKTT, the SAG was faster (2.5 ± 0.49 versus 3.3 ± 0.95 minutes; $p = 0.008$) and made fewer errors (0, [0–1] versus 3, [0–5] errors; $p = 0.006$). The SAG undertook fewer moves during knot tying (4 ± 1.4 versus 13.7 ± 2.5 movements, $p = 0.0004$) between explanation LKTT and follow-up, as well as between baseline and follow-up (8.5 ± 4.04 versus 14.9 ± 7.7 movements; $p = 0.02$) (Table 37.4). Our conclusions were that systematic approach training with mental training results in time reduction during laparoscopic knot tying—most likely secondary to less movements required to do knots. Repetitive mental rehearsal of the systematic

Table 37.1 Baseline comparison between control and systematic approach

Variable	Control	Systematic approach	<i>p</i> -Value
All movements	23.88 $\pm$ 9.31	24.44 $\pm$ 6.42	0.38
Total of errors	3 (2.5, 5.5)	3 (1, 4)	0.38
Overall time (seconds)	222.8 $\pm$ 72.92	199.1 $\pm$ 57.23	0.56
Moves to position needle	1 (1, 5)	2 (1, 8)	0.26
Needle drop	0 (0, 1)	0 (0, 1)	0.65
Moves for needle to pass tissue	2 (2, 2)	3 (2, 3)	0.06
Moves to do knots	15.41 $\pm$ 4.61	14.85 $\pm$ 7.77	0.65

Note: Values reported in mean $\pm$ standard deviation or median (interquartile range 1, 3).

Table 37.2 Follow-up comparison between control and systematic approach

Variable	Control	Systematic approach	p-Value
All movements	32 (19, 56)	21 (17, 23)	0.29
Total of errors	1 (0, 4)	1 (0, 2.5)	0.71
Overall time (second)	238 $\pm$ 64.63	140.75 $\pm$ 26.64	0.03
Moves to position needle	3 (2, 8)	2 (2, 3.5)	0.25
Needle drop	0 (0, 2)	0	1
Moves for needle to pass tissue	2 (2, 4)	2 (2, 2.5)	0.24
Moves to do knots	6.67 $\pm$ 4.73	4 $\pm$ 1.41	0.46

Note: Values reported in mean $\pm$ standard deviation or median (interquartile range 1, 3).

Table 37.3 Control group comparison between baseline and follow-up

Variable	Baseline	Follow-up	p-Value
All movements	23.88 $\pm$ 9.31	5.66 $\pm$ 18.77	0.36
Total of errors	3 (2.5, 5.5)	1 (0, 4)	0.37
Overall time	222.8 $\pm$ 72.92	238 $\pm$ 64.63	0.99
Moves to position needle	1 (1, 5)	3 (2, 8)	0.74
Needle drop	0 (0, 1)	0 (0, 2)	0.18
Moves for needle to pass tissue	2 (2, 2)	2 (2, 4)	0.11
Moves to do a knot	15.42 $\pm$ 4.61	11 $\pm$ 7	0.34

Note: Values reported in mean $\pm$ standard deviation or median (interquartile range 1, 3).

Table 37.4 Systematic approach group comparison between baseline and follow-up

Variable	Baseline	Follow-up	p-Value
All movements	24 $\pm$ 6.42	20 $\pm$ 4.32	0.86
Total of errors	3 (1, 4)	1 (0, 2.5)	0.72
Overall time	199 $\pm$ 57.23	140.75 $\pm$ 26.64	0.14
Moves to position needle	2 (1, 8)	2 (2, 3.5)	0.84
Needle drop	0 (0, 1)	0	0.39
Moves for needle to pass tissue	3 (2, 3)	2 (2, 2.5)	1.00
Moves to do knots	16 (8, 17)	4.5 (3, 5)	0.02

Note: Values reported in mean $\pm$ standard deviation or median (interquartile range 1, 3).

approach results in improvement in laparoscopic knot tying. Larger groups are required to determine improvements in different variables.

CONCLUSION

Surgery training has traditionally been conducted through an apprentice model, though recent changes secondary to new rules implemented in general surgery residency programs and the greater role in surgery of the laparoscopic approach have challenged both surgery professors and trainees in adjusting and developing new techniques in order to improve their learning experience.

Depending on the general surgery program, residents have a box trainer and/or laparoscopic simulator, which have shown to be effective in developing surgical skills and

transferring these skills to the operating room, and also decreasing operating time.^{4–6} In order to accomplish these results, the residents have to dedicate time toward practice.

As mentioned by Driskell and collaborators,¹⁰ an important factor for an adequate mental practice is that trainees are familiar with the procedure. Therefore, a curriculum for surgery training that summarizes the operative steps needs to be established. This will allow surgical residents to improve their skills and become more efficient and productive in real time during surgical procedures, making them more efficient and productive overall.

Mental practice is not a technique to substitute for physical practice, but it can be used as an extra learning technique that aids in developing skills. Most importantly, it is a technique that can be practiced and exercised during free time, and within 20–30 minutes prior to participating in the operation.

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The ergonomic minimally invasive surgical/endoscopy suite

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INTRODUCTION

Ergonomics is “the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well-being and overall system performance” as defined by the International Ergonomics Association.¹ Ergonomic considerations across a variety of fields have driven many efforts to maximize efficiency, counter fatigue/strain, and heighten safety. These efforts have given rise to numerous strategies (e.g., mandatory breaks), which have been employed by such industries as air traffic control, translation services, computer science, and even professional mountain climbing.^{2–4}

Yet, the field of surgery has continued to lag behind in implementation of sound ergonomic practices.⁵ This has largely been due to two factors: a lack of appreciation for the consequences of ergonomic errors and the surgical culture, which fosters self-forfeit and sacrifice by practitioners in the care of patients, even when faced with the prospect of injury. This resistance has persisted despite the minimally invasive revolution, which has completely changed surgery and the manner in which surgeons experience it.

Despite its less invasive nature for patients, laparoscopic surgery imposes greater physical and psychological burdens onto surgeons, amplifying their stress and risk of injury.^{6–10} The physical challenges of minimally invasive surgery (MIS) encompass barriers to direct anatomic access, dramatic decrease in space and degrees of freedom to work, and lack of direct view of the target anatomy.¹¹ The psychological demands arise from altered perceptions with no tactile feedback, substitution of two-dimensional (2D)

target view in place of the standard three-dimensional (3D) view, and contention with the fulcrum effect. Moreover, the operating room (OR) environment, which must maximally accommodate the surgeon and patient to enhance operative flow, is often inadequately designed and set up for MIS. For all of these reasons, the occupational hazards of laparoscopic surgery persist, manifesting as stress, fatigue, and/or injury in 87% of its regular practitioners. The implications of this finding are tremendous, highlighting the potential to compromise patient safety in the OR immediately and shorten surgeon longevity eventually. Simply performing MIS cases on a regular basis will subject practitioners to its perils, irrespective of age, experience, gender, height, or handedness.

Numerous studies have demonstrated consistent ergonomic risk factor violations by nurses and surgeons in the OR during laparoscopic surgery^{12–14} and their ultimate consequences.^{11,15,16,17} Berguer et al. have assessed the motions in the axial skeleton of surgeons during MIS versus open surgery.¹⁵ They found a more erect but static position for the head, neck, and axial spine during laparoscopic procedures. Moreover, participants exhibited forward-shifted center of gravity (CG) during MIS. The ramifications of static posture and forwarded CG during MIS pertain to immediate musculoskeletal strain and potential for consequent injury over time, as well as compromised performance of task. A survey study of MIS surgeons found high rates of fatigue/strain/injury and implicated poor instrument design as a primary cause (74%).¹¹ Surgeons identified posture adjustments as most employed counter-strategy to their physical symptoms (84%). Of note, nearly 60% of participants related minimal education/awareness with respect to proper ergonomic guidelines for practice. A more recent multicenter

prospective study led by our group demonstrated the physical and mental strains faced by surgeons in practice.¹⁶ Seventy-nine percent of surgeons reported pain and fatigue in the last 24 hours. This resulted in interference with personal relations and sleep, 42% and 49% of the time, respectively. Surgeons also reported mean pain of nearly 5/10 after a full day of open or laparoscopic surgery with greatest impact of pain on posture, stamina, mobility, and concentration. Forty-eight percent of surgeons were concerned pain would shorten their careers.

These studies underscore the urgency and need for efforts focused toward enhancing the interaction between surgeons, equipment/instruments, and their surrounding environment in the ergonomic minimally invasive surgical/endoscopy suite of the future. In parallel with these efforts, established international guidelines aimed at optimizing ergonomics must be adopted by the surgical profession as a whole. Simply put, a paradigm shift is needed from surgeons operating in unaccommodating environments to surgeons operating in environments designed to complement them and their patients to optimize operative flow, prevent injury, and maintain safety.

OPTIMIZED ERGONOMICS THROUGH ENHANCED WORKFLOW

The need to optimize the OR environment in order to improve safety, efficiency, and workflow has gained a new urgency with the rapid expansion of MIS and the increasing complexity of its cases.¹⁸ No longer are traditional OR setups and equipment designs adequate to accommodate the minimally invasive surgeon, patient, or OR staff. As such, there has been a gradual transition to more intelligent design to improve ergonomics, operative workflow, and patient safety.

Improving work space and function for the surgeon

During the early days of laparoscopy, ORs accommodated few, simple MIS procedures.¹⁸ Accordingly, their design tailored to open surgery had to be endured by pioneers of laparoscopy who were starting the MIS revolution. When a laparoscopic case was scheduled in these ORs, they were equipped with bulky laparoscopic rolling carts cramped with equipment, cathode ray tube monitors, and wires. One cart was positioned at the foot of the bed with one monitor providing a low-quality image. Video recording and image capture capabilities were not available. With minimal room to store laparoscopic equipment and wires, the operative field was often crowded or had to be continuously attended to, in order to prevent tangled wires and tubes. Operative tables could not appropriately adjust to the desired heights and positions to enhance the conduct of MIS operation by employing gravity as a way to gain exposure to the patient's

anatomy. This outdated equipment and OR designs promoted inefficiency and amplified risks of fatigue, strain, and injury to all engaged in the conduct of laparoscopic surgery (Figure 38.1a and b).

Since the early days of laparoscopy, many modifications have been made to the surgeon's surroundings to facilitate the conduct of MIS.¹⁸ These changes have included a compact laparoscopic tower usually incorporated into the construct and design of the OR. It provides an organized space to store tubing, wires, foot pedals, consoles, and other vital laparoscopic equipment while serving as a mounting source for suction and irrigation canisters, reducing clutter, and augmenting the surrounding space. Often, CO₂ flow originates from a central source outside the OR, eliminating the need to store and change tanks intraoperatively. There are numerous ceiling-mounted monitors that can be manipulated to display high-quality images from a variety of angles. They can also display images from a variety of sources, affording concomitant computed tomography, magnetic resonance imaging, ultrasound, or fluoroscopic or endoscopic image analysis during MIS. Video recording and image capture capabilities are standard. Operating tables are adjustable to ideal heights and positions required for MIS (Figure 38.1c).

Future efforts should broadly target cutting-edge technologies to allow surgeons maximum control of the OR environment with minimal tactile manipulation to achieve an ergonomically intelligent design.¹⁸ Functions such as monitor control, laparoscopic console device controls, radiographic image view or manipulation, video/image recording, communications (teleproctoring and telepresence), and computer access should be automated



Figure 38.1 The evolution of the MIS operating room: 15 years ago (a and b) versus a contemporary suit (c). (Courtesy of Dr. Roger Voigt, Chief of Pediatric Surgery, University of Maryland Medical Center.)

to respond to voice commands or hand gestures to protect against contamination and further lessen workloads. A recent simulation study conducted at the Simulation to Advance Innovation and Learning (SAIL) center at Anne Arundel Medical Center compared the feasibility of image manipulation during surgery using hand gestures along with the Kinect sensor and the Leap Motion sensor, compared to traditional tactile mouse manipulation.¹⁹ When evaluating the effectiveness and efficiency of touchless interaction devices, there was no significant difference between the performance of the mouse and the touchless input devices.

Improving work space and function for the charge nurse and OR staff

Laparoscopy also introduced new challenges to the OR staff.¹⁸ Minimally invasive cases required increased work and attention with regular adjustments of monitors, lights, cords, foot pedals, insufflation, video recorders, CO₂ supply, etc. These controls were often positioned far away from each other with minimal consideration for convenience. As such, more movement, noise, and distraction was generated as various team members strived to meet the needs of the case and surgeon. These translated to compromised workflow and safety for everyone in the OR.

Over time, efforts to reorganize vital controls and make them more accessible to a few key personnel reduced traffic and countered inefficiency.¹⁸ The charge nurse usually plays a central role in the flow of surgery. Therefore, special attention has been paid to maximize their function from a main workstation. This has entailed ready access to controls for lights, video recorders, printers, sound systems, motor controls, as well as the laparoscopic control tower, all concentrated at or near a compact computer desk where they perform other duties such as charting. Even buttons for various room functions should be arranged in a thoughtful manner to expedite workflow. A power “on/off” button with an indicator light for the various laparoscopic console devices should be present to the right of the light controls. Other buttons on this panel should allow the charge nurse to position ceiling-mounted monitors and video cameras.

Future efforts will also aim to provide voice and gesture control to the charge nurse and other OR staff to adjust monitors, console devices, radiographic images, video/image recorders, and computers. These efforts will enhance function and reduce the number of personnel and thus traffic to most efficiently perform each surgery.

Improving work space and function for the anesthesia staff

The MIS revolution has also shed light on important considerations for the anesthesia staff. A vital concept in anesthesia care, based on the “sterile cockpit rule,”²⁰ is

complete focus by the practitioner and lack of distractions during the critical phases of induction and emergence to ensure patient safety.²¹ With the potential for additional movements, adjustments, noise, and distractions during MIS, it became important to contemplate and refine the anesthesia workstation to optimize the function of the anesthesiology staff and meet their professional demands.

The area designated for the anesthesia staff is now at the head of the table and often illuminated by a separate adjustable light source controlled by the anesthesiology staff.¹⁸ A video monitor is also regularly devoted to this area providing the anesthesia staff the opportunity to track the progress of the case and simplify any coordinated efforts and/or communications between the surgeon and anesthesiologist. Finally, only critical equipment or setup is kept near the operative field, positioned to not restrict access to the patient by the anesthesiology staff.

Optimizing patient position and safety

Foremost in the considerations of operative flow is the patient.¹⁸ The progress of MIS has revealed a primary challenge, preserving immediate access to patients despite more surrounding equipment and setup near the operative field. To ensure this challenge is met, patients are now positioned center in the room with efforts to minimize unnecessary setup and equipment around them. This allows easy access to the patient in case of an emergency. Constant attention is also paid to removing unused instruments and equipment off the patient and the operative field. All overlying monitors, drapes, and equipment are easily and immediately moveable away from the patient and staff to allow access to the patient with maximal functional space, when necessary.

Otherwise, patients are best protected during MIS cases with meticulous care in their positioning and padding according to the needs and specifics of the case to prevent injury.¹⁸

Future efforts will continue to design and utilize more compact equipment and setup in the OR to further organize the surgical theater and enhance workflow around patients.

ENHANCING THE ERGONOMICS OF THE SURGEON

Evidence-supported stance and posture

Ergonomically sound postures during laparoscopy that maximize benefits have been described by several studies. The space occupied by the operating surgeon should be clear and allow for posture adjustments by the surgeon on a regular basis to counter fatigue and strain.¹⁵ Research has characterized the ideal arm positions during MIS, hung to the sides of the surgeon with elbows flexed in a 90° angle.²²

Dramatic wrist flexion or extension should be avoided with effort to keep wrists in a neutral position.²³ Monitors should be positioned in parallel with the visual trajectory of the surgeon and operative instruments to encourage a 15°–20° downward gaze.^{24,25}

Women in minimally invasive surgery

The physical strains of laparoscopy have often been most impactful on female surgeons.²⁶ Women have faced ergonomic disadvantages at two key fronts with respect to minimally invasive surgery and instrument and operating table design. Studies report persistent dissatisfaction among female surgeons with the design and feel of laparoscopic tools, starting in training and lasting well into practice.²⁷ Women are also at a disadvantage when it comes to table height, frequently employing the strategies of higher shoulder elevation or standing on a stool to accommodate an ergonomically inept table design.²⁶ This jeopardizes patient safety in the short term and surgeon longevity in the long term. These disadvantages may also have a potential impact on operative times and costs, which remain to be elucidated.

Accordingly, ergonomically intelligent design of laparoscopic instruments and ORs must give high priority to improving the experience of female minimally invasive surgeons. These efforts entail implementation of variable or adjustable surgical instruments with consideration of user digit length and width, which are likely the key determinants of appropriate hand/tool interactions.²⁶ Moreover, the surrounding equipment and setup must include proper adjustable tables that accommodate surgeons of both genders and diverse physiques.

Minimally invasive assistant surgeon

While the focus of operative ergonomics has traditionally been on the surgeon, other staff have largely been ignored.²⁸ This is most notable for surgical assistants who regularly assume less than ideal postures and positions to accommodate the surgeon and, as such, are subject to greater risks of strain and injury. According to one study during simulated laparoscopic Nissen fundoplication, assistants often shifted and maintained disproportionate weight (70%–80% of their body weight) on one lower limb while retracting tissues or manipulating the camera. As a result, they assumed greater risk of fatigue, strain, and injury. Additionally, the “target effect” was described in this group, the tendency to exert arm extension and body lean to prevent camera sway off proximal targets. The “target effect” promotes additional stress for assistants.

Strategies to enhance ergonomics for surgical assistants involve the use of adjustable camera holders and retractors to relieve assistants of prolonged static holding positions.²⁸ Furthermore, simulated training sessions may be

used to pre-train assistants to facilitate their acquisition of ideal ergonomic practices prior to live surgical experience. Finally, modifications of the operating table and patient positioning, including use of stirrups, may allow the assistant to work more in line with the trajectory of surgery and reduce the risks.

SPECIAL CONSIDERATIONS FOR FUTURE DEVELOPMENT

Microbreaks

The impact of breaks during surgery has previously been investigated as a viable countermeasure to surgeon stress.^{29,30} One study randomized surgeons to perform operations in the conventional manner versus taking 5-minute breaks every half-hour during surgery.⁵ They found breaks enhanced performance and reduced fatigue, strain, pain, stress/workload hormone levels (cortisol and testosterone), intraoperative “events,” and error rates for surgeons without significant prolongation of operative times.

A recently conducted multicenter prospective study assessed how the introduction of intraoperative targeted stretching microbreaks (TSMBs) impacts surgeon pain and function (results pending publication).³⁰ Surgeons and OR staff from four medical centers rated pain/fatigue, physical and mental performance using validated scales during two operative days: one day without implementing TSMB, and the other including standardized (2 minute) guided TSMB at appropriate 20- to 40-minute intervals throughout each case. TSMB improved surgeon postprocedure pain scores in the neck, lower back, shoulders, upper back, wrists/hands, knees, and ankles without a significant impact on operative time. This study concluded intraoperative TSMB may represent a practical and effective means to reduce surgeon pain, enhance performance, and increase mental focus without extending operative time.

Laparoscopic instrument

With the expectation that MIS will continue to play a major part in the future of surgery, there is a need to invest major effort in the ergonomics of its instruments, which have not been significantly evaluated for more than 20 years. Specifically, the traditional ring handle designs of most laparoscopic instruments are ergonomically deficient and have been associated with increased hand strain and injuries, both acute and chronic.³¹ These handles cause injury by concentrating high pressures on bony prominences of hands and fingers, as well as consistent promotion of counter-neutral hand and wrist positions. Furthermore, as described earlier, current instruments lack a dynamic design to accommodate various genders, physiques, and applications. Some experienced surgeons have adopted strategies in the use of these inadequate instruments to prevent injuries (e.g.,

not inserting their thumbs in the ring handle and palming the instrument).³¹

In this context, several authors and studies have proposed alternative handle grip designs to alleviate surgeons of this very important problem. Most recently, with consideration of 22 recommended criteria to optimize the ergonomics of instrument handles,³² an ergonomically intelligent “prototype handle” (PH) for laparoscopic instruments was designed and tested,³¹ which distributes pressures broadly over the hand surface and promotes more natural finger, hand, and wrist positions. This study found efficiency of task execution increased while pain levels of participants decreased with use of the PH versus the traditional ring handle. Over 64% of participants preferred the PH. Other studies have used improved ergonomic guidelines to propose superior handle designs for laparoscopic needle drivers³³ and dissection forceps.³⁴

These studies highlight the persistent void in modern ergonomically sound surgical instrumentation. There is an urgent need for better design of such instruments that will incorporate consideration of the anatomic, physiologic, and ergonomic demands of individual surgeons.

Image quality and visual comfort scale

High-quality imaging is essential for optimal surgical performance and outcomes.³⁵ Standards have yet to be determined and established to ensure high-quality image displays in ORs or for other image-dependent specialties (e.g., radiology).

Studies have proposed several key determinants of ideal image quality and validated methodologies for image appraisal. Implicated factors for ideal image include resolution, contrast, brightness, sharpness, color, and focus.^{36–40} One simulation study evaluated these metrics and devised the Maryland Visual Comfort Scale (MVCS) tool to accurately assess the visual comfort of individual surgeons.³⁵ This rating scale was validated and was sensitive in detecting discrepancies in image quality, a key first step to devising an image sensory assessment tool for laparoscopic surgery.

The benefits of 3D imaging during MIS have been investigated. Several simulation studies have shown benefits with reduced task times and/or performance errors when 3D imaging is used.^{41–44} Others have found the 3D cameras confer no benefit with respect to performance time and may subject practitioners to additional physical and visual stress.^{45,46}

Future studies are required to further refine visual comfort assessment tools and to fully characterize any ergonomic and/or workflow benefits with 3D minimally invasive surgery for surgeons. Finally, the impact of augmented reality and image registration on cognitive loads needs further exploration.

Robotic surgery

The surge in the use of robotic systems has been propelled by two important factors: the continued growth in global demand for MIS and cutting-edge technological contributions of the

robot to MIS, allowing 3D perception, enhanced degrees of freedom, motion scaling, and tremor reduction.⁴⁷

While some studies have concluded improved ergonomics or expedited task performance on robotic systems in comparison to laparoscopy,^{47–53} the true impact of this new technology remains to be fully defined. In general, robotic surgery demands longer operative times, and its ergonomic hazards may target alternative anatomic regions (e.g., cervical spine as opposed to lower back), which will manifest more broadly among practitioners with continued use. Thus, efforts should be concentrated on formulations of guidelines and education for surgeons who utilize the robot to ensure proper ergonomic practices and maximum benefit and protection. In this regard, expenditure of further research initiatives is needed in the future.

CONCLUSION

The ergonomic minimally invasive surgical/endoscopy suite of the future must consider the function, safety, and efficiency of each member of the operative staff in order to foster seamless collaboration between the surgeon, anesthesiology staff, and nursing and to optimize MIS flow and outcomes. This will require educational efforts to update surgical staff on up-to-date guidelines and implementation of programs such as “microbreaks” during surgery so that MIS is less invasive for the operative staff, as well as the patient.

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Energy sources in minimally invasive surgery

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INTRODUCTION

Energy devices are used ubiquitously in the operating room for almost all surgical procedures. In minimally invasive surgery (MIS), these include anything from a traditional monopolar laparoscopic L-hook, to more advanced ultrasonic dissectors and bipolar devices. Despite their proven utility and usability, intraoperative injuries related to their use are not uncommon and largely avoidable. Energy devices in MIS can be especially hazardous due to the inherent nature of the instruments, which are largely outside the field of view and have the potential to transfer energy to tissues in mechanisms that lead to iatrogenic injuries. Also, due to the loss of tactile feedback in MIS, surgeons are often unaware of elevated temperatures at the instrument tip, which can also lead to inadvertent injuries. Possible adverse events related to energy devices include electrosurgical burns, injuries related to current diversion or collateral thermal spread, operating room fires, and interference with implantable devices (e.g., pacemakers and cardiac defibrillators). This chapter summarizes various forms of energy in MIS, as well as adverse events that can occur and best practices to mitigate the risk of such injuries.

COMMON ENERGY DEVICES IN MINIMALLY INVASIVE SURGERY

Electrosurgery

Electrosurgery (e.g., “diathermy,” “Bovie”) uses radiofrequency (RF) alternating current in order to raise intracellular temperatures to achieve tissue vaporization, desiccation, and/or protein coagulation. Unlike true “cautery” (e.g., branding iron), electrosurgical devices produce a large current through the patient, potentially causing electrosurgical injuries in various locations outside the immediate vicinity

of the instrument tip. The electrosurgical unit (ESU) can deliver RF energy at defined levels of power, current, and/or voltage. In most operating rooms, the generator is typically set at a specific power, thereby delivering a prespecified amount of energy per unit time, regardless of whether the “cut” or “coag” button is activated (e.g., “30 coag” and “30 cut” both deliver 30 Watts of power). Throughout activation, these functions provide various levels of current modulation, resulting in greater voltage (and therefore thermal effect) with the “coag” function compared to the lower-voltage “cut” function. The greater voltage with “coag” has significant implications during MIS and significantly increases the likelihood of electrosurgical injuries, such as collateral thermal spread, current diversion, interference with cardiac implantable devices, and many others. A survey of the American College of Surgeons reports that approximately 75% of surgeons use higher-voltage “coag” most commonly, and that one-third have a tendency to employ these settings at high power levels beyond 40 Watts, thereby further increasing the risk of injury to patients.¹

Monopolar and bipolar devices both utilize electrosurgery using a closed circuit that passes through the patient and ESU via two electrodes. With monopolar devices, one electrode is included in the tip of the handheld devices (“active electrode,” such as the Bovie pencil), and the second is the flat/wide “dispersive electrode” pad attached to the patient. Bipolar devices have both electrodes within the device. Many bipolar devices have advanced configurations, such as impedance measurement properties to optimize hemostasis and cutting blades to divide desiccated tissue.

Ultrasonic energy

Ultrasonic devices are highly versatile devices that convert electrical energy to mechanical energy in the jaws of the instrument that vibrate at ultrahigh frequency, and when

applied to tissues, leads to vaporization, desiccation and/or protein coagulation. Several factors dictate the resultant tissue effect with these devices, including the frequency of blade excursion (higher-frequency “MAX” leading to more efficient cutting but less hemostasis), the degree of compression of the tissues between the jaws (greater compression improves cutting but decreases hemostasis), and tension on the tissues such as from lifting to provide more efficient cutting. The oscillating (lower) blade can also be used in the same manner as a scalpel for tissues that are under sufficient tension. These devices have significant advantages over electrosurgery, namely, due to the lack of current passing through the patient, eliminating the risks of electrosurgical burns, current diversion, or electromagnetic interference with implantable devices.

ADVERSE EVENTS

Injuries related to energy devices can lead to significant consequences. In the case of electrosurgery, injuries are estimated to occur at an incidence of approximately 40,000/year² or approximately 1–2 per 1,000 operations during laparoscopy.³ Almost 20% of surgeons have reported personally experiencing a stray electrosurgical burn injury during laparoscopy, while 50% know of a colleague who has experienced the same event.¹ The impact is also significant at the level of the provider, institution, and health-care system, with hundreds of millions of dollars spent annually for medical-legal claims related to such electrosurgical injuries.^{4,5}

Current diversion in MIS

The bulk of the length of instruments in MIS is located outside the surgeon’s field of view on the monitor, frequently in contact with other intra-abdominal structures without the surgeon’s knowledge. It is not uncommon for surgeons to assume that as long as the metal tip of the instrument is in the field of view, and that as long as the surgeon is careful enough not to activate the device when in proximity to important structures, that no injuries will occur. This assumption is fundamentally wrong, as stray current can be generated elsewhere, with or without intact insulation, and lead to potential injuries. Up to 70% of injuries are not recognized at the time of surgery and can cause significant patient morbidity.^{6–8}

Insulation failure is a common source of injury during laparoscopy,¹ whereby RF energy devices, which are equipped with insulation along their entire shaft, may present with a break in insulation causing stray current and possible injury. Defective insulation is commonly invisible to the naked eye or with careful inspection. In fact, smaller insulation breaks concentrate and focus current through a smaller surface area of contact with tissues, thereby creating a greater current density and greater resultant thermal

effect from stray current. For this reason, it is recommended that institutions screen instruments routinely for insulation failure using active electrode monitoring systems.⁹

Given that the patient is part of the circuit, another potential source of injury is when current is diverted outside of its intended path to other conductors or to the ground. These “alternate site injuries” can occur if the patient is in contact with a metal object that deviates current outside the intended circuit, such as stirrups, table brackets, intravenous fluid poles, and even electrocardiogram monitoring wires through *antenna coupling*. Antenna coupling is a phenomenon whereby the active electrode transmits and receives electromagnetic waves to other adjacent conductors when activated (such as laparoscopic tools, laparoscope, or wires) without direct contact through nonconductive media (e.g., air or instrument insulation). The reception of the electromagnetic wave by the second conductor is subsequently converted to current, resulting in a previously nonelectrically active wire now becoming electrically active, potentially causing an inadvertent injury. Often in laparoscopic surgery, several wires are running parallel to a wire that is conducting alternating current for RF electrosurgery. For example, a monopolar hook dissector wire can transmit its energy and therefore induce a current in an adjacent handheld “Bovie” wire or to the laparoscope wire through antenna coupling, despite the fact that the wires are protected from insulation. This phenomenon has shown to significantly increase cutaneous and trocar incision burns.^{10–12} In order to decrease the risk and magnitude of injury, operating room personnel are advised to avoid bundling electrosurgical wires to other wires, laparoscope camera cords, and other conductors, and to use the lowest energy (lowest power and voltage) necessary to obtain the intended tissue effects. This can be done, for instance, by placing the ESU generator and laparoscopic tower on opposite sides of the tables to avoid parallel running wires.

Similarly, capacitive coupling can occur through the development of an electromagnetic field around an instrument that is conducting alternating current. Should this field be strong enough (when using high-power or high-voltage settings) or in the proximity of another conductor (e.g., laparoscope camera, laparoscopic grasper/dissector, cannula, or other instruments), it can induce a current in this nonelectrically active conductor. Common examples of capacitive coupling in MIS include single-port surgery, where instruments are in very close proximity to one another, or where the electrosurgical cable is secured to the drapes by being wrapped around a metal clamp and a current is induced in the clamp. Also, if a metal trocar is used in MIS, a monopolar device through this trocar will induce a current in the trocar; however, since the trocar passes through the abdominal wall, the current tends to dissipate throughout a large surface area, and in most cases this causes a negligible thermal effect on the tissues. For this reason, it is advised that trocars be used only if they are either entirely metal or plastic. Hybrid trocars (such as

those with a plastic abdominal anchor) are rarely used and not recommended because the stored charge in the metal component can build up without the opportunity to unload itself on the abdominal wall. If this stored charge comes into contact with intra-abdominal viscera, the circuit will be completed and the current will pass through the bowel, potentially causing a burn injury.

Table 39.1 lists several steps MIS surgeons can take to decrease the risk of capacitive coupling. One of these important recommendations is to avoid open-air activation of electrosurgical devices without touching the target tissue. Should a scenario be created whereby current diversion occurs, open activation will maximize the risk of injury by diverting a large proportion of the current and energy through this alternative path. However, if the device is activated once the tip of the instrument is touching the target tissue, the majority of the current and energy is still transferred through the intended circuit, thereby minimizing the current and thermal effect through the alternative pathway.

Last, current diversion can occur via direct coupling, which occurs when one conductor directly makes contact or arcs current to another metal. This can occur intentionally, such as when a vessel is grasped with metal pickups and the active electrode is activated while its tip is in contact with the grasper in order to seal the vessel. In laparoscopic surgery, direct coupling can also occur inadvertently if the active electrode is activated while touching another conductor, such as the laparoscope camera or a metal instrument. Often, these instruments are also in contact with nontarget tissues outside the monitor (such as bowel), putting them at risk of injury.

Injuries related to active electrode

For MIS surgeons, active electrode injuries are particularly dangerous because of the lack of tactile feedback and knowledge of the residual heat at the tip of the instrument, even while the instrument is not activated. These injuries are especially notorious with bipolar and ultrasonic

instruments, whose tips can reach very elevated temperatures. Approximately 15% of experts assume that the thermal effect in bipolar instruments is restricted to the tissue between the two jaws of the active electrodes, whereas, in fact, surrounding tissue temperature can rise high enough to cause cell death ($>60^{\circ}\text{C}$) several centimeters away.^{13,14} Another common mechanism of injury is from collateral thermal spread to vulnerable structures such as bowel, vascular structures, or the biliary tree, due to excessive activation of high-energy settings. These risks can be minimized by using the lowest energy necessary to achieve intended tissue effects—by decreasing the power on the generator, using a low-voltage current (e.g., “cut”), or using short bursts of activations.

ARGON BEAM PLASMA COAGULATOR

The argon beam plasma coagulator (APC) is a monopolar device that uses current to ionize argon gas and to arc current from the active electrode tip to tissues from a distance of 1–2 cm. This form of high-voltage current can be effectively used to superficially coagulate and desiccate tissues using a no-touch technique, whereby the current is “sprayed” onto the tissue—a process called *fulguration*. Fulgurating with APC, or other monopolar instruments, can be particularly useful for hemostasis of capillary-oozing raw surfaces, such as liver and spleen, where tissue effects are kept superficial with minimal penetration. Also, since argon gas is emitted, this also helps to clear the surface of any blood that impairs visualization of the target tissue. During endoscopy, noncontact fulguration is effective for managing superficial mucosal lesions (e.g., arteriovenous malformations, radiation proctitis¹⁵).

Risks of APC to patients include excessive flow of argon gas into the peritoneal cavity, potentially causing gas embolisms or abdominal compartment syndrome with hemodynamic instability. Operators should use the lowest effective flow rate of argon gas and keep at least one port open during use to allow argon gas to escape. Also, the active electrode should be kept away from the target tissue and at an

Table 39.1 Best practice for decreasing the risk of electrosurgical injuries in minimally invasive surgery

- Use the lowest power setting necessary for the intended tissue effect
- Use the current with the lowest voltage possible for the intended tissue effect (i.e., “cut” as opposed to “coag”)
- Use active electrode monitoring systems for inspecting insulation on electrosurgical instruments
- Avoid activation of electrosurgical devices in open air
- Use brief (2–3 seconds) intermittent activations
- Activate the instrument only when the active electrode is entirely in the field of view
- Use either all metal or all plastic cannulas
- Clear the electrode tip of built-up eschar (increases the risk of current arcing)
- Avoid bundling cords and various instruments together
- Place unused electrosurgical devices in an insulated holster

Source: Adapted from Feldman L et al. (eds.) *The SAGES Manual on the Fundamental Use of Surgical Energy (FUSE)*. New York, NY: Springer; 2012 [22]. The Society of American Gastrointestinal and Endoscopic Surgeons Fundamental Use of Surgical Energy curriculum; <http://www.fuseprogram.org>.

oblique angle to minimize the risk of embolism. During endoscopy, the energy should be adjusted to minimize the risk of full-thickness thermal injury when controlling bleeding. It is generally advised to keep the power at 20 W using a modulated high-voltage setting (“coag”) for thin bowel wall (e.g., cecum, duodenum). Also, argon gas should be regularly suctioned to prevent overdistending the bowel.

ENDOSCOPY

Energy devices are employed ubiquitously during endoscopic procedures, most commonly using RF electrosurgery in the form of monopolar (e.g., snare, argon plasma coagulation, “hot” biopsy forceps, sphincterotomy device during endoscopic retrograde cholangiopancreatography, endoscopic submucosal dissection, and RF ablation balloon array) and bipolar circuits. True cautery can also be employed using heated probes. When RF electrosurgery is used during endoscopy, the same principles and guidelines apply as for open and MIS surgery in order to avoid electrosurgical burns. In addition, adequate bowel prep is required—especially during colonoscopy where methane gas poses a risk of explosion with the use of electrosurgery. Mannitol bowel prep should be avoided, as it is associated with increased levels of methane.^{16,17}

The two most significant complications that can result from the use of energy in the gastrointestinal tract are bleeding and perforation. To minimize these risks, the settings of the generator need to be adjusted according to the thickness of the bowel wall; hence, it is tolerant to transmural energy transmission. For instance, the stomach and the rectum have thicker muscular layers compared to the duodenum and the right colon, which are thin and at higher risk of perforation with a given energy setting. Another complication during therapeutic endoscopy is post-polypectomy syndrome, which occurs secondary to full-thickness thermal injury of the bowel wall and localized peritonitis, but without an actual perforation.¹⁸ Such patients tend to present the day following the procedure with localized peritoneal signs and fever, with imaging studies showing no signs of perforated viscus. Management involves observation, fluids, bowel rest, antimicrobial therapy, and serial examinations.

Monopolar RF is most commonly used during snare polypectomy, with a risk of bleeding and perforation of less than 5% and 0.5%, respectively.^{19–21} Because low-voltage current (“cut”) has minimal collateral thermal spread, it is associated with higher rates of post-polypectomy bleeding. It is therefore recommended to use a higher-voltage setting (e.g., “coag,” “blend”), with the smallest snare necessary to avoid collateral injury. Another strategy to minimize bleeding involves applying a high-voltage current (“coag”) on a pedunculated polyp only until the tissue blanches, followed by the use of low-voltage “cut” current to guillotine the polyp. Finally, lifting the polyp away from the bowel wall during activation, or injecting saline at the base of the polyp into the submucosa to “lift” the mucosa, can decrease the likelihood of deep thermal spread and full-thickness injury.

The latter technique is particularly helpful for resection of large and flat lesions.

Endoscopists using the snare for polypectomy should also pay attention to the degree of current density that is applied to the base of the polyp. The greater the thickness of the base around which the snare is tightened, the larger the surface area through which the current is delivered, and therefore the lower the current density and resultant thermal effect. Therefore, wider polyps typically require a greater amount of energy for resection, which can lead to perforation. Similarly, if the snare wire is tightened excessively and ends up “buried” in the polyp tissue, the surface area is again increased, requiring greater energy levels necessary to perform the polypectomy.

Other causes of injury with RF energy include current diversion and direct coupling. For example, if part of the active electrode that is delivering the current is still within the working channel of the endoscope, it can couple current to the tip of the endoscope. Endoscopists should also be careful not to activate the device near a metal clip within the lumen of the bowel as this may cause metal-to-metal arcing of current and unintended direct coupling to the bowel wall. Last, it is not uncommon for the tip of a pedunculated polyp that is being resected with electrosurgery to make contact with the opposite side of the bowel wall (**Figure 39.1**). As energy is applied, current can pass through this alternative circuit potentially burning the bowel.

In summary, surgical energy devices have proven highly useful for a broad range of applications in the operating room and in endoscopy suites, and as a result, have become widely adopted. Despite their utility, they are nevertheless becoming increasingly complex and can cause significant harm to patients if not used appropriately. Surgeons should acquaint themselves with the basic functionality, the various pitfalls, and how to troubleshoot them in order to operate both effectively and safely.

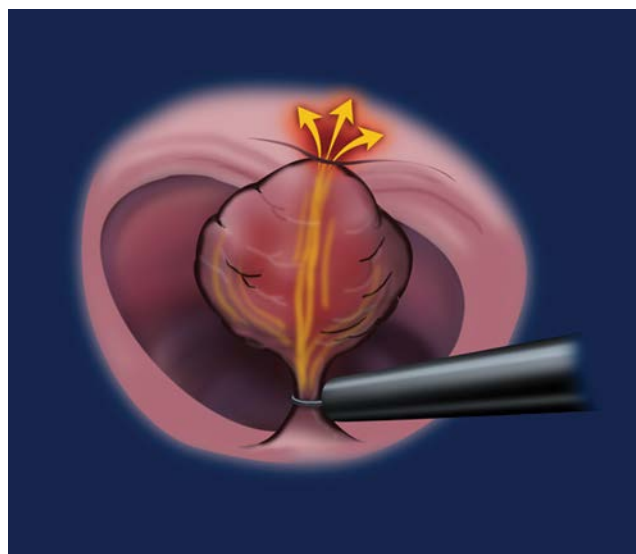


Figure 39.1 Direct coupling during polypectomy.

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Anesthesia for laparoscopy: What does a surgeon need to know?

CINDY M. KU AND STEPHANIE B. JONES

INTRODUCTION

Minimally invasive laparoscopic surgery has significantly decreased the perioperative risks for many surgical patients. With a reduction in postoperative pain, blood loss, and time to recovery, laparoscopic surgery is categorized as a low acuity procedure in the latest American College of Cardiology/American Heart Association perioperative guidelines. Many laparoscopic procedures are done on an ambulatory basis, and patients who may not be candidates for open abdominal procedures are often deemed sufficiently optimized for laparoscopic surgery. The physiologic alterations caused by pneumoperitoneum, however transient, can pose significant challenges for the anesthesiologist, especially in patients with multiple and severe comorbidities. There are also specific components of an anesthetic for laparoscopic cases such as depth of neuromuscular blockade and pain management. This chapter provides a brief overview of such challenges and discusses several anesthetic management considerations with which surgeons should be familiar.

PHYSIOLOGIC CHANGES DURING LAPAROSCOPY

The creation of carbon dioxide pneumoperitoneum induces physiologic changes that may cause significant duress for patients with underlying cardiac and pulmonary diseases. Hypercarbia from exogenous carbon dioxide activates the sympathetic nervous system, which results in tachycardia, hypertension, increase in myocardial contractility, and arrhythmias. In addition, the elevated intra-abdominal pressure (IAP) alters respiratory mechanics and can induce significant cardiovascular changes.

Respiratory mechanics and effects

Peritoneal insufflation limits caudad excursion of the diaphragm and instead shifts the diaphragm cephalad. This leads to early closure of small airways and therefore atelectasis and a decrease in functional residual capacity. The pneumoperitoneum also decreases chest wall compliance, resulting in elevated peak and mean airway pressures.¹ These alterations in respiratory physiology lead to the need for assisted ventilation under general anesthesia. While these changes are transient in healthy patients, such effects may not be well tolerated in patients with severe respiratory diseases such as chronic obstructive pulmonary disease. Kilic et al. have demonstrated that respiratory mechanical alterations such as reduction in vital capacity and forced expiratory volume in 1 second (FEV1) from laparoscopy and steep head-down Trendelenburg position during robotic prostatectomy persist for more than 5 days after the surgery and after discharge.² The reduction in compliance along with increased airway pressures from elevated IAP and bronchospasm in patients with severe reactive airway disease can result in worsening hypercarbia and hypoxemia, resulting in catastrophic pulmonary vasoconstriction that can lead to right heart failure. Insufflation in patients with significant respiratory disease should be performed gradually so as to detect the earliest signs of significant perturbations, and gasless abdominal wall lift techniques, if available, would be preferred in these patients.³

Laparoscopic surgeries have been performed successfully under neuraxial anesthesia for patients with severe pulmonary dysfunction at baseline.⁴ While a neuraxial anesthetic (spinal or epidural anesthesia) could be considered if the risk of prolonged mechanical ventilation is significant, patient cooperation, anesthesiologist's vigilance, and close communication between the surgeon and the anesthesiologist are critical to

the success of such an approach, and will require a meticulously individualized plan of care.⁵ In addition to standard intraoperative monitoring as defined by guidelines established by the American Society of Anesthesiologists, which include continuous electrocardiography, continuous pulse oximetry, noninvasive blood pressure measurements, temperature, and end-tidal carbon dioxide, an arterial line for frequent arterial blood gas monitoring in the perioperative period should be considered in patients with severe pulmonary dysfunction.

Cardiovascular effects of laparoscopy

The creation of pneumoperitoneum—from the insertion of trocar or needle, to the stretching of peritoneum—can lead to dramatic and rapid-onset vagal-mediated bradyarrhythmias and even asystolic arrest.⁶ It is important to have anticholinergic agents such as atropine and glycopyrrolate immediately available prior to peritoneal insufflation. Bradyarrhythmias can typically be resolved by immediate desufflation; communication between surgeon and anesthesiologist is key during this critical period.

The elevated IAP can lead to varied hemodynamic responses. At low insufflation pressures (below 15 mm Hg) and in euvoletic patients, the venous return is augmented by blood from the splanchnic circulation. At IAP above 15 mm Hg, the inferior vena cava becomes compressed, leading to a decrease in venous return. In addition, carbon dioxide exerts direct effects such as systemic arteriolar vasodilatation and myocardial depression; though the effects are usually short lived, they can still potentially result in significant organ hypoperfusion in patients with severe cardiovascular diseases, which may lead to an increase in morbidity.⁷ Last, hypercarbia leads to increases in pulmonary vascular resistance.

Healthy patients can tolerate mild to moderate intraoperative hypercarbia that will resolve at the end of the case with the cessation of insufflation and transient increase in minute ventilation, known as permissive hypercarbia. However, hypercarbia is poorly tolerated by patients with moderate to severe pulmonary hypertension at baseline and can lead to further restriction in pulmonary blood flow that results in right ventricular failure. Patients with pulmonary hypertension need careful preoperative evaluation by cardiologists and anesthesiologists and may not be candidates for prolonged laparoscopic procedures.

NEUROMUSCULAR BLOCKADE AND LAPAROSCOPY: HOW DEEP SHOULD THE BLOCKADE BE?

Neuromuscular blockade using nondepolarizing acetylcholine receptor antagonists is required in order to create pneumoperitoneum for surgery. Many surgeons routinely ask for deep neuromuscular blockade with the goal of optimizing the laparoscopic surgical field, while anesthesiologists may be hesitant to produce such conditions due to concerns for

postoperative residual neuromuscular blockade. Residual blockade, defined as a train-of-four (TOF) stimulation ratio of less than 0.9 as measured by peripheral nerve stimulation with or without acceleromyography, can cause postoperative respiratory complications such as hypoventilation, upper airway obstruction, and aspiration.⁸ Residual blockade can be prevented by administering reversal agents, acetylcholinesterase inhibitors such as neostigmine, as early as possible in the case. Neostigmine inhibits the degradation of acetylcholine at the neuromuscular junction and thereby increases the concentration of acetylcholine available to displace the nondepolarizing neuromuscular blockade agents from the acetylcholine receptors. Reversal with neostigmine is clinically effective when there is at least one TOF peripheral nerve twitch, which suggests that at least 10% of the acetylcholine receptors are unoccupied. In addition, advocates for moderate neuromuscular blockade express concern that inadequate depth of anesthesia may not be appreciated, and that deep neuromuscular blockade nearly eliminates the possibility of patient movement in response to inadequate anesthesia.⁹

Deep neuromuscular blockade is defined as no more than two post-tetanic twitches using a peripheral nerve stimulator and representative of nondepolarizing muscle relaxants such as rocuronium occupying over 95% of acetylcholine receptors in the neuromuscular junction. Proponents of deep neuromuscular blockade state that the lower IAP requirement needed to produce a pneumoperitoneum for laparoscopic surgery¹⁰—as much as a 40% decrease—may be associated with less side effects such as pain and oliguria, as well as a decrease in the adverse physiologic effects associated with elevated IAP as previously described.¹¹ A Cochrane systematic review in 2014 on low versus standard IAP for laparoscopic cholecystectomy found no significant difference in operative conditions¹²; however, even though postoperative shoulder pain was reported to be reduced, there was no significant difference in analgesic consumption for this iatrogenic, transient pain. Likewise, no significant difference in operating conditions was found with either low or standard insufflation pressure in minimally invasive laparoscopic gynecological surgeries.⁹

The new neuromuscular blockade reversal agent, sugammadex, has been approved by the U.S. Food and Drug Administration. Sugammadex is a cyclodextrin derivative compound that reverses neuromuscular blockade by binding to steroidal nondepolarizing muscle relaxants such as rocuronium and vecuronium. The onset of action of sugammadex is within minutes; at the maximum recommended dose of 16 mg/kg, full reversal from deep neuromuscular blockade with two post-tetanic twitches to TOF of 0.9 takes approximately 2 minutes.¹³ There are limitations to sugammadex, such as renal excretion of the sugammadex-rocuronium compound, 1% incidence of anaphylaxis, interference with oral contraceptives, and the economics of the drug. Nevertheless, sugammadex provides anesthesiologists a new method of neuromuscular blockade reversal, especially when deep blockade is warranted due to patient comorbid factors such as obesity.

PERIOPERATIVE PAIN MANAGEMENT FOR LAPAROSCOPY

The advantages of laparoscopic surgery when compared to open procedures are primarily decreases in pain and recovery time. As many laparoscopic procedures in various surgical specialties are now performed on an ambulatory or overnight observation basis, optimal analgesia and minimization of side effects and anesthetic complications are key in the development of the perioperative plan for each patient. The development of ERAS (Enhanced Recovery After Surgery) protocols is in response to such needs. A recurring theme in various ERAS protocols is to minimize the use of systemic opioids for analgesia so that the undesirable effects of opioids, including sedation, respiratory depression, and ileus may be kept to a minimum.¹⁴ In addition to scheduled nonopioid analgesics such as acetaminophen, nonsteroidal anti-inflammatory drugs such as ketorolac and celecoxib, gabapentinoids such as pregabalin or gabapentin, α -2 agonists such as clonidine and dexmedetomidine, and ketamine and lidocaine infusions are all common opioid-sparing multimodal analgesia strategies for laparoscopic abdominal surgery. Regional anesthetics such as the transverse abdominis plane (TAP)¹⁵ block have been shown to decrease opioid consumption¹⁶ and hospital stay,^{17,18} particularly in the colorectal surgery and gynecologic patient population. Other regional anesthesia techniques such as rectus sheath block, paravertebral block, and ilioinguinal/iliohypogastric block can also be appropriate components of an opioid-sparing analgesic plan.¹⁹

COMPLICATIONS OF LAPAROSCOPY

For anesthesiologists, the most catastrophic complications in laparoscopic surgeries are misplacement of the Veress needle or trocar into vasculature, and pneumothorax. Vascular injury can lead to hemorrhage and hypovolemic shock, with initial physiologic signs consisting of hypotension and a sudden drop in end-tidal carbon dioxide as pulmonary blood flow is significantly diminished. Intravascular carbon dioxide insufflation may result in gas embolism, with an initial increase in end-tidal carbon dioxide but persistent hypotension. Patients should be placed in a head-down, left lateral decubitus position, if possible, in order to keep the gas in the apex of the heart and prevent further entrainment into the pulmonary circulation. Pneumothorax can result from rupture of bullae in patients with chronic obstructive pulmonary disease or from iatrogenic passage of carbon dioxide from the peritoneum into the chest cavity. Intraoperative signs and symptoms may consist of a sudden increase in peak airway pressures and a decrease in oxygenation with diminished breath sounds. Pneumothorax may progress to tension pneumothorax with decreased end-tidal carbon dioxide reflecting a decline in cardiac output. During these crisis

events, clear and closed-loop communication between surgeon and anesthesiologist is critical in working toward a good patient outcome.

A more common anesthetic complication associated with laparoscopy is postoperative nausea and vomiting (PONV). There are patient-specific risk factors for PONV, such as gender, history of motion sickness, age, and cigarette use.²⁰ For patients at high risk of PONV undergoing laparoscopic surgery, aggressive prophylaxis using a combination of long-acting antiemetic such as a single dose of dexamethasone or transdermal scopolamine and a short-acting antiemetic such as ondansetron is appropriate.

CONCLUSION

Minimally invasive laparoscopic surgery has made surgical treatments possible for patients whose comorbidities may exclude them from open surgical procedures. The specific physiologic effects and anesthetic needs of laparoscopic procedures require careful perioperative planning. Early referral to a preoperative assessment clinic or anesthesia consultation for the medically complex patient is beneficial.

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Access and imaging in minimally invasive surgery



Charles Alston and Georgette Seabrooke Powell, *Modern Medicine*, 1940. Oil on canvas, 17 × 19 feet. Mural located in the atrium of the Mural Pavilion at Harlem Hospital Center, located at 512 Lenox Avenue in Harlem, New York City. (© NYC Health+Hospitals/Harlem, New York City, permission granted.)

In 1936, a superintendent of Harlem Hospital Center rejected four of the sketches that were intended for a group of on-site murals commissioned by the Works Progress Administration's Federal Art Project (1935–40). He reasoned that the representations of everyday African Americans were too overtly “Negro” and that blacks “may not form the greater part of the Community” in the foreseeable future. However, the team of seven artists, led by Charles Alston, would not be deterred. With financial backing of the hospital's first African American surgeon, Dr. Louis T. Wright, they garnered popular support from the community, leading to a reversal of the decision. The murals were finally completed in 1940.

The murals deteriorated over time and were at some point covered by plaster, but they were recently rediscovered and restored to their former splendor. Alston and Powell's *Modern Medicine* is part of a diptych, situated

opposite *Magic in Medicine*. The two works frame a dialogue between modern, Western medical treatment, and ancient, non-Western healing practice, presented as a contrast between two imagined scenes in the United States and Africa. *Modern Medicine* is a racially integrated depiction of the medical field. It highlights major figures in the advancement of medicine, such as microbiologist Louis Pasteur, alongside African American pioneers in the field, such as Wright, who in addition to helping save the murals was a prominent member of the NAACP, the oldest and largest civil-rights organization in the United States, and an advocate for racial equality in medicine. The work also features Myra Logan, Alston's future wife, as a nurse holding an infant. At the time, Logan was an intern at the hospital, but she later became a surgeon and the first woman to perform an open heart surgery.

Access in minimally invasive surgery

MARGARET E. CLARK AND ROBERT B. LIM

INTRODUCTION

Trocar access should be a basic skill in all surgeons who perform laparoscopic surgery. The Fundamentals of Laparoscopic Surgery (FLS), which is a requirement for board certification of General Surgeons, teaches the techniques, and those that are FLS-certified should be familiar with not only the techniques but also the risks and benefits of each and the treatment for the complications of trocar insertion. There are multiple different trocar insertion techniques and ways to gain access in minimally invasive surgery. In the 2012 Cochrane review, Ahmed et al. identified 13 different laparoscopic entry techniques from 28 randomized controlled studies.¹ There is no one insertion technique that is superior to another. Trocar-related injury rates are thankfully low, but these injuries can be fatal, especially if they are not recognized. Worldwide, among meta-analyses and large multicenter studies, the risks are 0.2–0.9/1,000 and 0.4–1.8/1,000 for vascular and bowel injuries, respectively.^{1,2} It is important

that all surgeons who do laparoscopic procedures are properly trained in appropriate trocar placement, they know more than one insertion technique, and they are vigilant about recognizing complications. There are four main laparoscopic entry methods with variations in location and type of trocar used. A combination of techniques can be used as well, such as using a Veress needle to establish pneumoperitoneum followed by trocar placement with an optical viewing trocar. Every entry technique has the potential of a complication. No matter what method is used, the first step of the operation once the camera is within the abdomen should be to inspect the area beneath the placed trocar to rule out injury.

Initial trocar placement should be near the umbilicus or in the left upper quadrant (LUQ) in abdomens without a previous incision. For those with a previous midline incision, the periumbilical entry should be avoided, and an open, Veress, or Optiview technique should be used several centimeters away from the previous incision. Ten steps for a safe laparoscopic entry can be seen in [Table 41.1](#).²

Table 41.1 Evidence-based criteria for safe laparoscopic entry: 10 steps

Step	Intervention
1	Suitability criteria: consider alternative entry for patients with risk factors such as previous surgery, obesity, or thin physique
2	Safety criteria: patient should be lying flat with an empty bladder; feel for the aorta and any masses; VN should be checked for spring action and gas patency
3	Incision: 10 mm vertical intraumbilical incision starting deep inside the umbilicus and extending caudally (if using this site for entry)
4	Insertion of the VN: at the deep umbilical pit, 90° to the skin, with or without elevating the anterior abdominal wall, in a controlled manner, inserting less than 2 cm of the needle tip
5	No movement of the VN after insertion
6	Safety abdominal pressure check: most reliably by using pressure less than 10 mm Hg
7	Safety abdominal pressure check for primary trocar: the pressure should be 15 mm Hg to achieve maximum safe distance
8	Vertical primary trocar insertion: inserted in a controlled two-handed screwing manner with only the tip inserted through the wall
9	Injury check: an initial 360° laparoscopic check for injury
10	Secondary trocar(s) insertion: inserted under direct vision in a controlled two-handed manner, avoiding inferior epigastric vessels

Source: Varma R et al. *Surg Endosc* 2008;22:2686–97.

VERESS NEEDLE

In the Veress needle (VN) technique, the surgeon places a needle into the abdomen establishing pneumoperitoneum prior to placing a trocar at either the same place or through a separate incision. Obtaining entry into the abdomen via VN followed by blind primary trocar insertion is the most commonly used technique worldwide, specifically among gynecologists.^{3,4} In a recent Cochrane review, they found that VN was associated with more failed entries, extra-peritoneal insufflations, and omental injuries,¹ similar to the results of a recent meta-analysis comparing VN to direct entry, even when considering patients with a history of abdominal surgery.⁵ The VN approach had four major complications versus none in the direct group, but this failed to show a statistical difference. However, there was a significant increased risk of minor complications, with a relative risk (RR) of 10.78, including preperitoneal and omental injuries.⁵ These injuries, though, are likely to be clinically insignificant. The operating surgeon needs to be aware of the loss of resistance while inserting the trocar that he or she will face when the pneumoperitoneum is entered.

The Veress angle of entry at the umbilicus should be 90°, inserting the needle tip no greater than 2 cm with selective abdominal wall elevation.² When inserting the Veress at Palmer's point, access is obtained 3 cm inferior to the costal margin in the left midclavicular line. Palmer's point should be used when there are known periumbilical adhesions, an umbilical hernia, or after three failed attempts at the umbilicus.⁶ This site is also used frequently on obese patients, especially in those whose abdominal weight hangs below their umbilicus. Different safety tests to ensure the VN has been correctly placed intraperitoneally have been described, including the aspiration test, injection test, recovery test, saline drop test, and initial intraperitoneal pressure test. The pressure test is most reliable, with opening pressure levels of less than 8 mm Hg yielding a sensitivity, specificity, positive predictive, and negative predictive value of 100%.⁷ A pressure of less than 10 mm Hg has also been described as a reliable indicator of appropriate access in obese patients.⁶ Another technique is to attach the insufflation gas to the VN during entry and watch for the drop in pressure as the needle enters the peritoneal cavity. Though previously wiggling the tip of the Veress needle has been described as a safety check, in doing so a small puncture injury may now become a 1 cm or greater sized injury in the viscera or vasculature; therefore, this move should be avoided.⁶

HASSON OR OPEN TECHNIQUE

The open technique is also referred to as the Hasson technique. This technique involves making an incision and dissecting down to the abdominal wall fascia, performing

ultimately a mini-laparotomy. The fascia and peritoneum are opened under direct vision and a blunt port is placed, secured by either placing stay sutures in the fascia or with a ballooned trocar. Though the Cochrane review showed that the Hasson technique is associated with less failed entries compared to the closed-entry technique, it did not show a difference in the incidence of visceral or vascular injuries.¹ There are considerably fewer reports of bowel and vascular injury in the literature.⁸ A big advantage to the open technique, and why some authors prefer it, is that any injury can be recognized and repaired immediately.⁹

DIRECT OR BLIND INSERTION

This technique is performed by placing a bladed or dilating trocar into the abdomen without establishing pneumoperitoneum and not visualizing fascia. Often the abdominal wall will be lifted by the surgeon or with towel clamps. This is probably the least used entry technique. Furthermore, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) *Manual of Quality, Outcomes, and Patient Safety* states that direct trocar insertion "should only be performed if the surgeon has extensive experience with the safe performance of [sic] the direct trocar insertion technique."¹⁰ Once the tip of the trocar has been inserted through the skin, the trocar is pushed through the fascia and muscle layer by continuous twisting and downward pressure, so the surgeon can easily realize when the trocar has entered the peritoneal cavity. The CO₂ gas stopcock is kept open, relieving negative pressure. It is postulated that the viscera falls off its parietal apposition prior to contact with the trocar.⁵ The laparoscope verifies position, followed by gas insufflation. An absolute contraindication to this technique is placing a trocar blindly near a previous open abdominal incision or a previously placed mesh.

OPTICAL VIEW TECHNIQUE/OPTIVIEW

Using the optical view (OV) technique, a 0° laparoscope is inserted into the sheath of a transparent nonbladed dilating, or blunt, trocar. The trocar is gripped with a palmar grasp, with the other hand holding the camera straight. This trocar is advanced slowly, using a twisting motion combined with downward pressure, while the surgeon watches all layers of the wall, visualizing entry into the peritoneum. The layers visualized should be the subcutaneous fascia, the anterior abdominal wall fascia, muscle, posterior fascia, preperitoneal fat, followed by the peritoneum (**Figure 41.1**). The Optiview has the ability to avoid intra-abdominal adhesions.¹¹ If on initial view of the abdomen through the clear tip, it reveals bowel that does not easily slide past the tip, this suggests an adhesion may be present, allowing for partial withdrawal and repositioning of the trocar. This

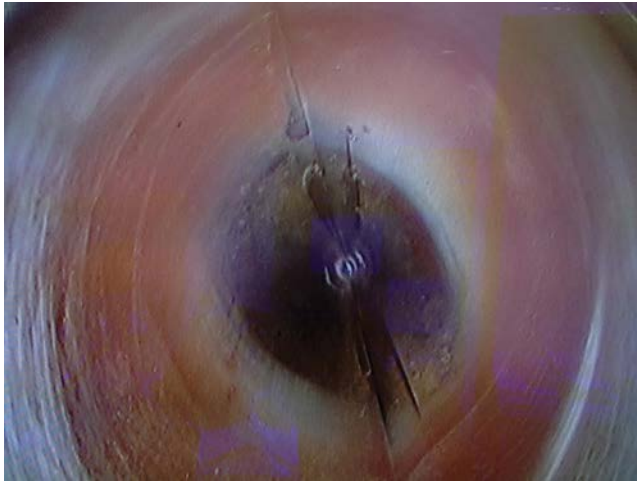


Figure 41.1 The layers of the abdominal wall, as seen through an optical viewing trocar.

allows for placement adjacent to an adhesion in a location that may have been susceptible to bowel injury with a blind access technique, including the VN.

The OV technique can be combined with the VN technique, using the VN to establish the pneumoperitoneum, followed by entry under visualization with the OV scope. To decrease risk of injury using this combination technique, the surgeon should have good control and use minimal downward pressure given potential for injury with the loss of resistance.

RADIALLY EXPANDING ACCESS

The technique is a variant of the VN technique. A radially expanding access system, the STEP trocars, was developed to minimize tissue trauma. The system uses a VN with an outside polymeric sleeve (Figure 41.2). Once insufflation is achieved the needle is removed, leaving the sleeve in place. Dilation of the sleeve can accommodate a 12 mm trocar. The theory in the use of this trocar is that since only one sharp instrument enters the abdomen, less tissue trauma occurs, and subsequently less bowel and vascular injuries.¹ However, in all trials comparing STEP trocars to traditional trocars, there was no significant difference in rates of vascular or visceral injuries.¹

SINGLE-INCISION LAPAROSCOPIC SURGERY

Single-incision laparoscopic surgery (SILS) was developed to reduce the number of ports needed for an operation for cosmetic reasons. There is different terminology to describe this technique, such as laparo-endoscopic single-site (LESS) surgery and single-port access (SPA).¹² This technique minimizes the number of ports placed. Data are lacking on access complications with SILS, but it is placed in an



Figure 41.2 One example of a radially expanding trocar, the STEP.

open technique, usually through the umbilicus. The incision is larger than a Hasson technique incision, but again is done under direct visualization. A platform is then placed with multiple trocars used through the single platform (Figure 41.3). Given that this access is similar to an open,



Figure 41.3 One example of a SILS platform.

Hasson, approach, previous surgery at the midline should be considered a relative contraindication. An international panel of experts at the 2014 American College of Surgeons meeting determined that single-incision surgery is safe in very experienced hands, has a unique cosmetic advantage, and has clinical outcomes that are similar to those of multiport surgery.¹³

ROBOTIC ACCESS

Ultimately there are no real distinctions between placement of robotic ports, and the initial port placement can be done by any of the laparoscopic access techniques described. Once the trocars are placed, the robot is then docked. In their initial experience with robot-assisted surgery, many surgeons will use traditional laparoscopic equipment to gain entry into the abdomen and then switch to the robot camera after the trocars are placed. This increases the cost of the operation. With newer-generation robot platforms that are easier to use and that have lighter cameras, some will use the robot camera for the initial entry, especially if they use the OV technique. Use of the robot platform comes down to the surgeon's preference, but the trocar placements should follow the same concepts as traditional laparoscopic approaches.

COMPLICATIONS: CONTROL OF BLEEDING

As stated before, the first step after gaining peritoneal access and establishing the pneumoperitoneum, regardless of technique, is to examine the area in the abdomen where the initial port and/or the VN was placed, looking for injuries. The incidence of bleeding complications laparoscopically ranges from 0.005% to 8.6% but is likely underreported.⁹ Some authors include hematomas and bleeding in the abdominal wall, but others only include major injuries to large vessels. The most common bleeding due to trocar insertion is abdominal wall bleeding, but bleeding can also occur in the mesentery, from the solid organs, and from retroperitoneal sources to include the vena cava, the aorta, the renal vessels, and the iliac vessels. One must also be aware of the internal epigastric artery when placing a trocar through the rectus abdominis muscle. Though usually not fatal, these bleeds do require hemostatic measures and can prolong an operation. In a meta-analysis comparing nonbladed dilating tip trocars to bladed ones, the nonbladed trocars had a lower relative risk of abdominal wall bleeding and overall complications. However, there was no difference in major complications. In a large-vessel injury, immediate conversion to laparotomy is the best method to control massive bleeding. Bleeding at the trocar site can be controlled by compression, facial closure device, internal or external ligation or coagulation, or even by using a balloon catheter for short-term tamponade.^{8,9}

INJURIES TO THE VISCERA OR SOLID ORGANS

Surgeons must also be cognizant of injuries to the hollow and solid organs. Again the rate of injury is very low, up to 1.8/1,000.¹ Often this occurs because of excessive pressure used when placing trocars or because of previous adhesions. While the initial entry can be made several centimeters from previous incision sites, this does not eliminate the possibility of an adhesion at the initial entry site.

Again recognition of this injury is paramount. When using the VN needle technique, aspiration through the needle is important, because if blood, bile, stool, or urine returns in the aspirate, then an injury must be present. This may not require a conversion to an open procedure, but that depends on the surgeon's skill, comfort, and extent of the injury. One technique for finding the injury is to leave the port or the VN in place and then gain laparoscopic access through another site. Once access is gained, the injured organ may be easier to identify if the trocar or VN is still in the place of injury.

SPECIAL CONSIDERATIONS: OBESITY

Most surgeons recognize the obese abdomen as a more difficult abdomen to enter due to wall thickness, especially in women. Despite this, none of the literature suggests that one method is superior over another. In a retrospective review of 139 obese patients (mean body mass index = 45.94 kg/m²), they found that VN was not only safe, with a complication rate of 0.72%, but effective as well, with a success rate of 98.28%.¹⁴ They advocate lifting the abdominal wall with towel clamps, which encourages detachment of the abdominal wall from the viscera, reducing the risk of injury, and also minimizes the risk of placing the VN into the omental fat, which affects the flow of gas through the needle tip. The VN placed at Palmer's point is seen in [Figure 41.4](#). Other bariatric surgeons favor placing



Figure 41.4 Insufflation by Veress needle at Palmer's point.

the patient in reverse Trendelenburg prior to initial entry in attempts to move the viscera away from the anterior abdominal wall. The OV technique has also been shown to be an acceptable alternative.¹⁵ Researchers have found that using the direct optical entry, when compared to the open Hasson, had reduced entry times, and less blood loss. Many will also use a combination of the techniques, with the VN to obtain a pneumoperitoneum and then an OV technique to gain trocar access via the LUQ with the patient in Trendelenburg position. Though all techniques can be used, there are limitations. When using the open technique, the incision may need to be larger than the port diameter to dissect down to the fascia, leading to leakage of pneumoperitoneum around the port site.

SPECIAL CONSIDERATIONS: THIN PATIENTS

Many insertions are done near the umbilicus because the amount of tissue between the skin and peritoneum is less. However, in a normal weight adult, the aorta is only an average of 6 cm deep from the umbilicus. This distance decreases with downward pressure on the trocar and muscle relaxation in the anesthetized patient, even down to 2 cm. This distance may also decrease in thin patients. As such, the aorta and vena cava are at risk during initial trocar entry. VN insufflation should be done at Palmer's point, and the initial trocar placement should be done with a pneumoperitoneum increasing this distance to these structures. Alternatively, a Hasson technique could be utilized, and because tissue dissection to the fascia will not be as extensive as in obese patients, an appropriate-sized fascial incision may be easier to attain, preventing loss of gas around the trocar.

EXITING THE ABDOMEN

A laparoscopic inspection of the entire abdomen should be done prior to exiting the abdomen. This inspection includes sites that are far away from the operative field and all of the trocar sites themselves. Bowel injuries can occur from the use of surgical energy, and these may occur far away from the operative field. Additionally, an accurate view may not be feasible with a 0° scope, and angle scopes should be utilized to ensure adequate visualization. It is recommended that the pneumoperitoneum pressure be lowered during part of the inspection to look for venous bleeding, especially from the abdominal wall and trocar sites. The trocars should be removed under direct visualization, watching the abdominal wall for bleeding that had been tamponed by the trocar and elevated intra-abdominal pressure. Finally, it is recommended that trocar incisions 10 mm or greater should be closed to prevent port site hernias, with at least the posterior fascia being closed.¹⁶ A transfascial suturing device here can help (Figure 41.5).

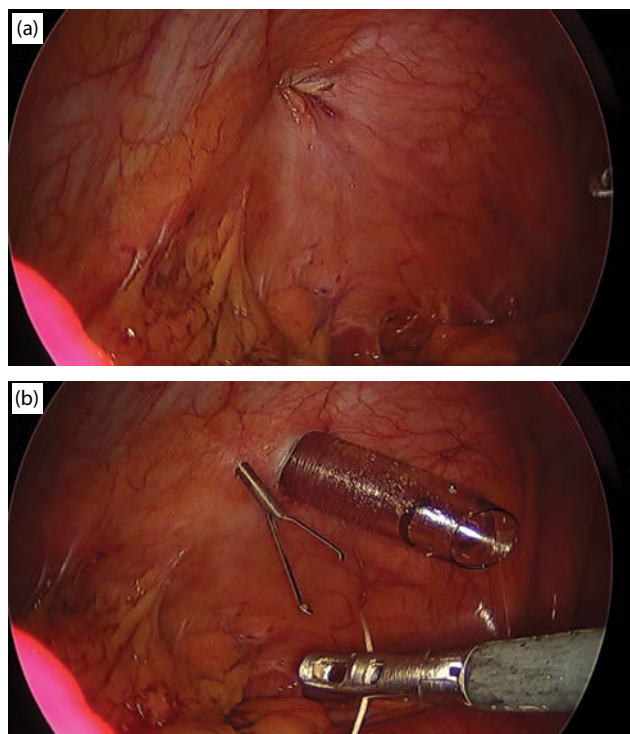


Figure 41.5 Transfascial suturing device being used.

CONCLUSION

Multiple techniques may be used to obtain access for minimally invasive surgery. It is imperative that the surgeon understands the potential complications and performs a thorough laparoscopic exam of the abdomen to ensure there are no missed injuries. Whichever technique is used should be used in a safe and controlled manner.

DISCLAIMER

The views expressed in this chapter are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.

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Single port and reduced port access

BENJAMIN SADOWITZ, ALEXANDER ROSEMURGY, AND SHARONA ROSS

INTRODUCTION

Single-site and reduced port access laparoscopic surgery have undergone dramatic growth and widespread adoption across many surgical disciplines over the past decade. This widespread growth necessitated the development of a standardized vocabulary to describe and discuss this revolutionary method of minimally invasive surgery. Thus, the Laparoendoscopic Single-Site Surgery Consortium for Assessment and Research (LESSCAR) was formed as an international, multidisciplinary group in 2009 to unify the basic terminology and protocols across surgical disciplines for laparoscopic single-site surgery.¹ LESSCAR reviewed over 20 existing names for single-site laparoscopic surgery in the literature; after much deliberation, they decided that the designation of laparoendoscopic single-site (LESS) surgery most closely embodied the broad aspects of this unique field of minimally invasive surgery and could comfortably be used across surgical disciplines.¹



Indeed, the LESS approach offers a unique, minimally invasive platform to undertake a wide variety of abdominopelvic surgical procedures through a single incision into the peritoneal cavity. We began utilizing LESS surgery for cholecystectomy in 2007 and quickly applied the LESS approach to all of our conventional laparoscopic operations. Thus, we systematically applied LESS surgery to a host of foregut and upper abdominal operations, as these are the focus of our practice.

It is important to keep in mind that the LESS approach to minimally invasive surgery does not preclude the addition of additional trocars as needed to undertake a safe and efficient reduced port access operation. Indeed, there are a variety of operations that require an extraction site for organ pathology too large to fit through the single incision made for the working instruments and camera. Furthermore, there may be a need for insertion of additional retractors, stapling devices, or implantable devices (i.e., the gastric band) that

preclude the possibility of using one incision. Nonetheless, for the surgeon who wishes to develop a LESS skill set, we encourage the use of a single incision approach “up front,” so to speak, as it is always possible to insert more trocars as needed during the course of an operation.

LESS FOREGUT SURGERY

LESS cholecystectomy

For those general surgeons interested in developing a LESS surgical skill set, cholecystectomy is an ideal starting point. Laparoscopic cholecystectomy is a common operation, familiar to all general surgeons, and does not involve any reconstruction ([Videos 42.1 and 42.2](#)). In fact, the technique of LESS cholecystectomy has become standardized, and, in our experience, proficiency can be attained after approximately 25 operations.² Multiple reports corroborate our operative experience and denote safe adoption of LESS cholecystectomy with a learning curve that is definable, safe, and short.^{3,4} In fact, after our first 100 LESS cholecystectomies, we adopted this method as our preferred method of cholecystectomy.⁵

There is no debate that conventional laparoscopic cholecystectomy is a tremendous advance over open cholecystectomy. However, LESS cholecystectomy offers many potential advantages over conventional laparoscopy including reduced pain, a speedier return to functional activities, and superior cosmesis. In addition, safety with LESS cholecystectomy is unarguable and comparable to conventional laparoscopy.³

Patient safety remains the most important component of any surgical approach. However, the importance of patient satisfaction with their scar cannot be overemphasized as, on some level, patients will always judge the quality of their operation by their cosmetic outcome. Patient satisfaction

with cosmesis after LESS cholecystectomy is quite remarkable and consistent across multiple studies.⁴ Although preoperative patient concerns before cholecystectomy do mainly focus on safety issues, postoperative attention, in our experience, typically shifts to cosmetic outcomes, recovery time, and return to functional activity.

LESS cholecystectomy provides other unique opportunities for patient satisfaction and cost savings. In particular, utilization of epidural anesthesia for LESS cholecystectomy offers a tremendous opportunity for decreasing operative costs while further increasing patient satisfaction with their operation. There are multiple studies in the literature demonstrating the safety and efficacy of utilizing spinal anesthesia for laparoscopic cholecystectomy.^{6–8} Our experience with epidural anesthesia for LESS cholecystectomy corroborates the results of these former studies and demonstrates a significant decrease in postoperative pain compared to those patients who undergo their operation with general anesthesia.⁹

LESS fundoplication for gastroesophageal reflux disease and giant hiatal hernia repair

We began offering LESS fundoplications for the treatment of gastroesophageal reflux disease (GERD) in 2008 ([Videos 42.3 through 42.6](#)). As with LESS cholecystectomy, the learning curve for LESS fundoplication is approximately 25 operations, and it has a safety profile similar to conventional laparoscopy.⁶ Once we determined where to place the laparoscopic instruments in the multitrocar port for the particular steps of the operation, both LESS fundoplication and LESS hiatal hernia repair ultimately became our standard of care over conventional laparoscopy.⁶

Early in our experience with LESS fundoplication, we compared the postoperative course and outcomes after LESS fundoplication to that after conventional multi-incision laparoscopy. We found that while the LESS approach required a slightly longer operative time, there were no discernible differences between these surgical approaches; both approaches provide salutary and similar relief in the frequency and severity of the symptoms of GERD. With continued application, we have become stronger advocates of the LESS approach for hiatal hernia repair and fundoplication. Even the most complicated circumstances (e.g., giant hiatal hernia, paraesophageal hernia) can be addressed using the LESS technique and patient satisfaction (e.g., pain, recovery, and cosmesis), as with cholecystectomy, is outstanding.

LESS Heller myotomy with anterior fundoplication for achalasia

For over 20 years, we have embraced laparoscopic Heller myotomy with anterior fundoplication for palliation of the symptoms of achalasia ([Video 42.7](#)). LESS Heller myot-

omy now represents an advance over the conventional multitrocar, multi-incision laparoscopic approach. As with LESS fundoplications and other LESS operations, the learning curve for LESS Heller myotomy with anterior fundoplication is definable, short, and safe.¹⁰ Furthermore, it provides the advantage of a “scarless” alternative while maintaining all the advantages of conventional minimally invasive operations. Most importantly, it provides palliation indistinguishable from the conventional laparoscopic approach.⁸

LESS, SINGLE INCISION, AND REDUCED PORT APPROACHES FOR BARIATRIC PROCEDURES

Gastric banding

Single incision and reduced port access for laparoscopic adjustable gastric banding (LAGB) are gaining momentum as many bariatric patients are concerned with their image and surgical scar appearance after undergoing an operation.¹¹ In their case series of 60 patients undergoing a reduced port access approach for laparoscopic gastric banding, Koh et al. demonstrated both the feasibility and safety of this method using conventional rigid laparoscopic instruments and cameras (although they did convert to a flexible-tipped camera as their technique evolved).¹¹ Similarly, Park et al. compared outcomes of patients undergoing the LESS approach for their gastric band versus those undergoing the conventional laparoscopic approach.¹² The LESS approach was associated with significantly lower pain scores and oral analgesic consumption compared to the conventional laparoscopic approach.¹² Other case reports demonstrate similar efficacy and safety with both reduced port and true single site approaches.^{13,14}



Sleeve gastrectomy

Traditional laparoscopic approaches to sleeve gastrectomy utilize anywhere from five to seven separate incisions. As with gastric banding, however, this surgical procedure can be undertaken via a single incision approach. Although there are no randomized controlled trials to date, there are multiple case studies demonstrating the safety and efficacy of the LESS approach for sleeve gastrectomy.^{15,16} This approach undoubtedly provides a superior cosmetic outcome to conventional laparoscopic approaches, and it may reduce postoperative pain in these patients as well.¹⁵

Roux-en-Y gastric bypass

Because it is both restrictive and malabsorptive, the Roux-en-Y gastric bypass is considered by many to be one of the “gold standard” operative procedures for morbid obesity. The weight loss obtained with this procedure is





significant and durable over the course of time. However, the traditional laparoscopic approach requires five to seven individual incisions for port placement. In addition, the technical challenges of the operation discourage many surgeons from attempting a single site or reduced port access approach.

Nonetheless, over the past decade, many bariatric surgeons are converting from the conventional laparoscopic approach to the Roux-en-Y gastric bypass and utilizing a single site technique. For example, Huang et al. demonstrated both the safety and efficacy of their single incision approach to the Roux-en-Y gastric bypass in a case report in 2009.¹⁷ Subsequent reporting by this same group demonstrated improved scar cosmesis and patient satisfaction with this method versus the multi-incision conventional laparoscopic approach for this operation.^{18,19} Lee et al. demonstrated similar results with their series of 100 patients undergoing two-incision Roux-en-Y gastric bypass.²⁰ In particular, their patients who underwent two-incision Roux-en-Y gastric bypass experienced minimal somatic pain and achieved excellent cosmetic results.²⁰



LESS, SINGLE INCISION, AND REDUCED PORT APPROACHES TO HEPATOBILIARY AND SOLID ORGAN PATHOLOGY

Pancreas and spleen



For splenectomy or distal pancreatectomy with or without splenectomy, we have adopted the LESS approach over conventional laparoscopy (Video 42.8). For distal pancreatectomy with or without splenectomy, the LESS approach requires an extraction site, and this is usually placed at the left anterior axillary line to avoid a visible scar when the patient looks in the mirror. The extraction site can also be hidden within the pubic hairline (or transvaginally in female patients) if the patient so wishes. The scar is approximately 3–4 cm in length and, given its size and location, is generally unapparent.

In our experience, LESS distal pancreatectomy with or without splenectomy is undertaken without any more consternation than what is experienced with the conventional multi-incision laparoscopic or robotic approach. This method is as safe and expeditious as with a conventional laparoscopic or robotic approach, and the associated cosmetic outcome and recovery are superior to either. Other institutions utilizing a single incision approach for distal pancreatectomy with or without splenectomy have reported similar results with regard to the safety profile of this method and its superior cosmetic outcome.^{21–23}

Liver

Conventional laparoscopic approaches for resection of benign and malignant liver and biliary tree lesions are

well-documented in the literature over the past two decades (Video 42.9).^{24–31} More recently, many surgeons who undertake these operations via a conventional laparoscopic approach are converting to LESS or single incision modalities.^{30,32–37} As new developments in technique, instrumentation, and standardization protocols occur, it is anticipated that LESS and single-site approaches to complex hepatic and biliary resections and reconstructions will continue to move to the forefront and replace conventional laparoscopic methods due to superior cosmesis, decreased postoperative pain, and rapid recovery times.^{30,32,36}

Adrenal gland

Since the early 1990s, resection of the adrenal gland for both functional and nonfunctional tumors is largely undertaken via a laparoscopic approach (Video 42.10). Using conventional laparoscopic methods for adrenalectomy typically requires three or four incisions for trocar placement. The approach is either retroperitoneal or transabdominal depending on surgeon preference and patient factors including lesion size and body habitus.

Over the past decade, however, many surgeons have adopted single-incision methods for resection of both functional and nonfunctional adrenal tumors. For example, the initial experience of Goo et al. with single incision laparoscopic adrenalectomy demonstrated that this is a safe method for adrenalectomy and provides excellent cosmesis.³⁸ A 40 patient case series of LESS adrenalectomies by Luo et al. also demonstrated the safety and efficacy of this method along with pleasing cosmetic outcomes.³⁹ When compared to conventional laparoscopy for adrenalectomy, single-site adrenalectomy appears to have a similar safety profile.^{40–42} In addition, the single-site method appears to be associated with less postoperative pain and a superior cosmetic result.⁴⁰

LESS, SINGLE INCISION, AND REDUCED PORT APPROACHES FOR COLORECTAL SURGERY

One of the advantages of LESS surgery is that it gives equal access to all quadrants of the abdomen and pelvis. Thus, the approach lends itself very well to colectomy and concomitant reconstruction. Unfortunately, many colectomies in the United States are still undertaken as “open” procedures; laparoscopic and robotic approaches are applied for a minority of colectomies, and the LESS approach is uncommonly utilized in patients undergoing laparoscopic operations.

Nonetheless, there are a burgeoning number of reports from centers across the United States and the world supporting LESS, single-site, and reduced port access approaches for colectomy.^{43–48} These approaches can be used for both right- and left-sided colectomies in addition to total colectomy.^{43–48} Although specimen extraction may require extension of the initial incision or a second incision, this can

be accomplished without notable cosmetic compromise. Our growing experience with LESS colectomy is consistent with our overall experience with LESS surgery, and we have adopted this method as our preferred approach for many of our colectomy cases (**Video 42.11**).

THE LESS APPROACH AND CONCOMITANT OPERATIONS

As mentioned previously, the LESS approach gives equal access to all quadrants of the abdomen and pelvis, making concomitant operations readily possible. We have undertaken concomitant operations including combinations of cholecystectomy, fundoplication, Heller myotomy with anterior fundoplication, inguinal hernia repair, hysterectomy, colectomy, and distal pancreatectomy with splenectomy. Other groups have corroborated our experience and demonstrated that a wide variety of concomitant operations are possible via a single incision or reduced port access approach.^{49,50}

CONCLUSIONS

The LESS and reduced port access approaches for a multitude of foregut and abdominopelvic operations are comparable in terms of patient safety to conventional laparoscopy. Furthermore, these approaches offer a clear advantage in terms of patient satisfaction with cosmesis. Proficiency can be obtained quickly, especially for those surgeons who have a foundational experience with conventional laparoscopy, as learned skills are interchangeable among a wide variety of operations. General surgeons and specialty surgeons alike should be prepared to meet the growing patient demand for these types of minimally invasive approaches.

VIDEOS

Video 42.1 Standardization of LESS cholecystectomy (<https://youtu.be/kF3PMYShDFY>).

Video 42.2 LESS cholecystectomy with epidural (<https://youtu.be/nH3jtjORrY>).

Video 42.3 LESS Nissen fundoplication with repair of giant hiatal hernia (https://youtu.be/KMdGx41L_DA).

Video 42.4 LESS Nissen fundoplication and new suture technology (<https://youtu.be/w8HYhuXZ6iE>).

Video 42.5 LESS Toupet fundoplication (<https://youtu.be/QITbToqDORU>).

Video 42.6 The role of the valve mechanism during fundoplication (<https://youtu.be/P5dTBj3ugEY>).

Video 42.7 LESS Heller myotomy with anterior fundoplication (<https://youtu.be/P3nIS59skss>).

Video 42.8 LESS distal pancreatectomy (<https://youtu.be/McloAYBQ7PU>).

Video 42.9 LESS liver cyst unroofing (<https://youtu.be/ff4eMrsIqKA>).

Video 42.10 LESS adrenalectomy (<https://youtu.be/v9GUAnNsKpQ>).

Video 42.11 LESS right colectomy (<https://youtu.be/W6iDREOMV9Y>).



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Diagnostic laparoscopy for benign and malignant disease

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INTRODUCTION

Indications for laparoscopic procedures have expanded with improvements in technology and experience. Even with advancements in quality of radiographic imaging, diagnostic laparoscopy (DL) continues to have a significant role in patient care. The benefits of this procedure include concurrent diagnosis and therapy, with decreased morbidity, length of hospital stay, and pain compared to laparotomy.

BENIGN

Acute Pain

Multiple studies have demonstrated that DL for abdominal emergencies is feasible, safe, and effective at diagnosing and treating the underlying disease process. While the majority of conditions can be diagnosed preoperatively based on laboratory and imaging studies, in 16%–28% of such patients, diagnosis remains elusive.¹ DL can lead to definitive diagnosis of the source of abdominal pain in 98.3%–100% of cases, and most patients can be successfully treated laparoscopically, with few conversions (0.15%–10%).^{2–4} DL has been applied to the diagnosis and treatment of perforated peptic ulcer, acute appendicitis, small bowel obstruction, biliary disease, pelvic disease, and colonic perforations. Additionally, in one study, the laparoscopic results were compared to those patients treated for similar processes with an initial open approach, and hospital length of stay was shorter.² In a prospective, multicenter study of 300 patients undergoing DL, 21% did not have a clear diagnosis preoperatively, with a change in operative strategy occurring in 5.6% of patients. In 30 (10%) patients, conversion to an open procedure was required due to adhesions (40%), local inflammation (40%), and bowel distention (20%).⁴ Major complications occur infrequently (1.9%–8%) with no mortality reported.^{2–4}

Most contraindications to laparoscopy are relative. Laparoscopy decreases venous return, so patients with hemodynamic instability, severe pulmonary hypertension, or ongoing congestive heart failure may require additional care and monitoring. Patients with bowel obstruction and significant dilation may be at increased risk of bowel injury during entry. Significant bowel distention or intra-abdominal adhesions due to prior surgery or generalized peritonitis may prevent sufficient pneumoperitoneum for adequate visualization. Patients with uncontrolled bleeding diathesis and late pregnancy may also require additional preoperative preparation.^{5,6}

Nonspecific acute abdominal pain (NSAP) is defined as acute abdominal pain with duration less than 7 days and uncertain diagnosis despite basic examination and diagnostic studies. The theoretic advantage of early DL in these patients is avoiding delays in treatment and the morbidity of a laparotomy. In these patients the role of early DL versus active observation is less clear. A systematic review of randomized controlled trials designed to address this question demonstrated improved diagnostic accuracy of the source of pain with DL, but no difference in morbidity, mortality, or recurrence of pain.⁷ Some studies have shown early DL decreases hospital length of stay, while another demonstrated an increase in patient's quality of life scores 6 weeks after DL compared with initial observation.^{7–11} Given its low complication rate, DL can be considered in patients with NSAP at the discretion of the treating surgeon, but further evidence is needed before it can become standard of care.

Multiple techniques for DL have been described. Placement of a gastric tube or urinary catheter is strongly advised. For general abdominal exploration, the patient should be placed in the supine position with both arms tucked, as extended arms can obstruct the surgeon's ability to evaluate the pelvis. Initial access to the abdominal cavity is most commonly described at the umbilicus with a cut-down technique. In the absence of significant bowel distention, access with a Veress

needle or optical entry trocar can be attempted. Patients with prior abdominal surgery should have the initial port placed far from prior incisions unless using the Hassan or open technique. Additional ports are placed under direct vision after successful insufflation to 8–15 mm Hg, depending on disease process or location in question. Usually working ports are placed at least 5 cm apart and centered 15 cm from the disease process. Full bowel exploration can be enabled by placing two ports on either side of the abdomen. An angled laparoscope is suggested to facilitate complete exploration. Drains, if necessary, can be placed through trocars prior to their removal. The literature emphasizes the need for a well-trained laparoscopic surgeon and experienced surgical support team to safely and effectively treat abdominal emergencies with laparoscopy.^{1–5,12}

Trauma

The main goal of DL in trauma continues to be the avoidance of negative laparotomy in patients with suspected intra-abdominal injuries, which has been described in up to 73% of patients.¹³ The avoidance of a negative laparotomy consistently is associated with decreased hospital length of stay and complications. Commonly described applications are anterior abdominal stab wounds with confirmed or equivocal penetration of peritoneum on local wound exploration, gunshot wounds with suspected tangential trajectory, diagnosis of diaphragm injury in thoracoabdominal penetrating trauma, and even suspected intra-abdominal injury despite initial negative workup.^{5,13–18}

Multiple studies conducted within the last decade support these indications for DL in trauma. Negative or nontherapeutic laparotomy was avoided in 57%–73% of patients. Sensitivity ranged from 90% to 97.6%, specificity 100%, and accuracy 98.6%–100%. Conversion rates ranged from 2% to 42%, and missed injury rates were 0%–1.3%. There were no intestinal missed injuries. The only missed injury described was a pancreatic injury that was beneath a retroperitoneal hematoma.^{13–17}

In a recent systematic review of 51 studies encompassing 2,569 patients that underwent DL for abdominal trauma, 51.8% of patients were spared a negative laparotomy. The studies were categorized by those utilizing DL as a screening tool, diagnostic tool, and therapeutic tool. For screening purposes (detection of peritoneal penetration or determining need for further exploratory laparotomy), the sensitivity of DL ranged from 86% to 100%, specificity ranged from 29% to 100%, and accuracy ranged from 52% to 100%. As a diagnostic tool, DL had sensitivity rates of <50%–100%, and accuracy ranged from 55% to 100%. Therapeutic laparoscopy was completed in 24% of patients within those studies; the most common organ repaired was the diaphragm. Based on this evidence, when utilized for screening peritoneal violation or the need for further open exploration, the sensitivity approaches 100%. For diagnostic and therapeutic purposes, the utility and accuracy of DL rely significantly on

the laparoscopic skill of the operating surgeon. Most recent studies report missed injury rates near 0%, but historically, sensitivity as low as 18% for gastrointestinal injuries has been noted.¹⁸ The most recent Eastern Association for the Surgery of Trauma practice management guidelines on the evaluation and management of penetrating abdominal trauma echo these results. The guideline supports the role of DL in limiting the negative and nontherapeutic laparotomy rates, as well as in ruling out diaphragm injury in thoracoabdominal penetrating wounds.¹⁹

To improve diagnostic results, a systematic approach to DL in trauma is essential. Appropriate preparation includes placement of gastric tube and urinary catheter and proper patient positioning with arms tucked and patient prepped from nipples to knees. This allows the table and patient to be maneuvered for optimal visualization and manipulation. Additionally, if there is suspicion of diaphragm injury, the potential for tension pneumothorax caused by pneumoperitoneum should be considered, and in some cases, tube thoracostomy may be needed preoperatively. Entry to the peritoneum is described most commonly at the umbilicus, and additional ports are placed based on injury pattern. A common distribution of ports is to place two additional 5 mm ports at the left and right paramedian location at the level of the umbilicus. This allows for visualization of both upper and lower abdomen, and thorough examination of the small intestine can be accomplished. Utilization of an angled laparoscope aids in visualization. In penetrating abdominal trauma, the peritoneal cavity can be inspected first for violation, and if the peritoneum was not violated, the procedure can be terminated. If peritoneal penetration is identified, a thorough, systematic approach to exploration of the entire peritoneal cavity is completed. The upper abdomen including the lesser sac needs to be inspected for free fluid, hemoperitoneum, solid organ injury, or hollow viscus injury. For thoracoabdominal wounds, the diaphragm needs to be investigated. Berg et al. showed that 32% of diaphragm injuries due to thoracoabdominal stab wounds detected at DL were not visualized on preoperative computed tomography (CT).²⁰ A similar systematic approach is applied to the lower abdomen, and if necessary, the ascending and/or descending colon can be mobilized. Laparoscopic repair of injuries to nearly all intra-abdominal structures has been described.^{5,13–16} The surgical team must always be prepared for emergent conversion to an open procedure, if necessary. Success in therapeutic laparoscopy for trauma requires availability of adequate instrumentation, appropriate surgeon and surgical support team skills, and a systematic approach to peritoneal exploration.

Bedside laparoscopy for the critically ill

Bedside DL for patients in the intensive care unit has been shown to be feasible and tolerable, even for those patients with hemodynamic instability. Several indications for this procedure exist, including sepsis of unknown origin,

systemic inflammatory response or metabolic acidosis with suspected abdominal pathology, and unexplained abdominal pain, fever, or leukocytosis. These patients often have an unreliable abdominal exam due to mechanical ventilation and sedation. They may be too unstable for transport for additional diagnostic studies. Additionally, the morbidity of an unnecessary laparotomy in this population is near 22%, and the mortality rate associated with the development of acute abdominal processes in these patients can be as high as 50%–100%.^{21,22} Bedside DL offers timely, safe, and accurate diagnosis without risk of transport. Relative contraindications for DL in this population include inability to tolerate pneumoperitoneum and a massively distended abdomen due to bowel obstruction or abdominal compartment syndrome. Many studies also excluded DL in those patients with uncorrected coagulopathy and intracranial hypertension. Failure to complete the procedure is most commonly due to significant intra-abdominal adhesions. The procedure time ranges from 10 to 70 minutes. Surgeons often limit pneumoperitoneum to 8–10 mm Hg in critically ill patients to minimize hemodynamic consequences, and this was generally tolerated well without having to escalate vasopressor use. Appropriate surgeon skills, support team capabilities, and equipment are required to accomplish these procedures at the bedside. Additionally, coordination and communication with anesthesia are crucial. Some procedures can be completed at the bedside, but often patients with positive findings are transferred to the operating room for definitive treatment. Critically ill patients with unexplained sepsis and hemodynamic instability were found to have high mortality rates with both positive and negative laparoscopic findings, but no immediate mortality related to the procedure has been described. The most common disease processes identified were acalculous cholecystitis, bowel ischemia, and perforated peptic ulcer disease.^{5,20,21}

MALIGNANT

Another application of DL is in the staging of various abdominal malignancies, most commonly esophageal, gastric, and pancreatic cancers. The rationale for completing preoperative DL in these patients is the avoidance of unnecessary laparotomy in those with occult metastasis, improvement in quality of end of life for patients with unresectable disease, and guidance of treatment decisions for neoadjuvant and palliative therapies.

Esophageal

Accurate preoperative staging for esophageal cancer is essential to guide treatment strategies and avoid futile surgery. Patients with advanced cancer, however, are candidates for neoadjuvant chemotherapy and radiation to improve survival. Currently, conventional CT scans are unable to detect small hepatic and peritoneal metastases and distant

lymph node spread, and this is the focus of DL in the staging of esophageal cancer. One retrospective review confirmed suspected pathologic celiac lymph nodes in 63% of patients, and identified unsuspected pathologic celiac lymph nodes in 14% of patients.²³ Another review identified peritoneal metastasis in 17% of patients undergoing DL, determining that in combination with endoscopic ultrasound, therapeutic decisions were impacted in 37% of patients.²⁴ A review of five retrospective studies evaluating DL in esophageal cancer reported that DL led to changes in staging in 8%–28% of cases, changes in management in 10%–24%, morbidity rates of 0%–3%, mortality rates of 0%, and false-negative rates of 5%.²⁵ The role of laparoscopic ultrasound (LUS) in addition to DL for staging of esophageal cancer has also been studied. Based on DL alone, 20% of patients had unresectable disease, which increased to 28% after LUS. The LUS focused on evaluation of the liver, intra-abdominal esophagus, stomach, perigastric lymph nodes, and periaortic lymph nodes.²⁶ One additional consideration in the staging algorithm of esophageal malignancies is the growing utilization of positron emission tomography (PET) scanning. None of the reviewed studies utilized PET scanning in the diagnostic workup, so it is difficult to make specific recommendations. PET scans have yielded sensitivity and specificity of 51% and 84% for locoregional lymph node involvement, and identified metastasis in 6%–15% of patients previously missed by CT.²⁷

The procedure is begun as previously described for DL. After thorough examination of peritoneal and hepatic surfaces, the gastroesophageal junction is examined by elevating the left lateral hepatic lobe. Further examination for local extension of disease and lymphadenopathy is then completed, and biopsies are obtained if necessary.^{26,28}

Gastric

The potential benefit of adding DL to the staging evaluation for gastric cancer is identification of peritoneal and hepatic metastasis previously missed by imaging, and distinguishing resectable (T3) from unresectable (T4) disease. This allows patients with advanced disease to avoid unnecessary laparotomy and aid palliative decisions. Currently, there is support for routine utilization of DL in staging of suspected T3 and T4 lesions, with little evidence showing benefit in T1 and T2 lesions. DL in gastric cancer has an accuracy of 93%–100% for detecting peritoneal metastasis, 90%–100% for hepatic metastasis, and was found to change management in 8.5%–59% of cases.^{28–31} In one study, 17% of patients with unsuspected metastasis had a negative preoperative PET scan.³² There is little data on utilizing DL for T1 and T2 disease, with only one study finding a change in management in 3.8% of patients undergoing DL.³³

The DL procedure is initiated as previously described, with full inspection of the peritoneum. Examination of the anterior surface of the stomach and perigastric, porta hepatis, and gastrohepatic lymph nodes is completed. In posterior lesions, the lesser sac is opened to inspect the

posterior surface of the stomach. If ascites is present, it should be aspirated and sent for cytology. If no ascites is present, 200 mL of saline should be instilled, aspirated, and sent to pathology.²⁸

Pancreatic

The majority of patients with pancreatic cancer present with advanced disease not amenable to resection. Appropriate preoperative evaluation is essential to adequately stage patients and provide guidance for additional therapies. The role for DL in pancreatic cancer remains controversial as to whether it should be offered routinely or selectively. In the recent Cochrane review addressing this question, 40% of patients with resectable disease based on imaging were deemed unresectable at surgical exploration. By adding DL to the workup, that rate decreased to 17%.³⁴ The literature reports accuracy rates of DL to detect unresectable disease of 87%–98%, sensitivity of 93%–100%, and specificity of 80%–100%. An unnecessary laparotomy can be spared in 4%–36%; however, DL can miss 6%–17% of patients with metastasis.^{28,35–37} Many studies have attempted to determine which patients would benefit most from DL. The most consistent findings are tumor size >3 cm, CA19-9 levels >150 U/mL, tumor location in the body or tail, and equivocal preoperative imaging.^{38–40} Some additional predictors are weight loss and jaundice.³⁸ Identification of metastasis at DL prevents patients from undergoing unnecessary laparotomy, and laparoscopic exploration is associated with a decreased hospital length of stay compared to an open exploration.⁴¹ An additional study looked at patients who were deemed unresectable at subsequent exploratory laparotomy after DL, and the most common locations metastases were identified was posterior liver surface, lesser sac, paraduodenal retroperitoneum, and proximal jejunal mesentery. This study proposed the need to perform an extended DL, including entry to the lesser sac and mobilization of the duodenum, to decrease the false-negative rate.³⁷ Patients with locally advanced disease without metastasis may also benefit from staging DL. If metastasis can be ruled out, these patients may be referred for other treatment modalities. Additionally, if a tissue diagnosis has not yet been obtained, this can be performed by DL.^{40,42}

The procedure is performed as previously described for DL focusing on evaluation of peritoneal surfaces, perihepatic spaces, bowel surfaces, lesser sac, root of transverse colon mesentery, ligament of Treitz, paracolic gutters, and pelvis. Some studies suggest an increase in diagnostic accuracy with the addition of LUS, which can further evaluate for liver metastasis, vascular invasion, and lymphadenopathy.^{43–45}

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Laparoscopic ultrasound in surgery

MAURICE E. ARREGUI AND PIYUSH AGGARWAL

INTRODUCTION

Ultrasound is probably one of the most underused intraoperative diagnostic tools. Diagnostic ultrasound uses sound waves to create an image, which can be used to guide, investigate, diagnose, or treat various conditions without side effects. These waves when reflected back from various tissue interfaces are converted by the unit to continuous grayscale images on the ultrasound monitor. Strong reflectors present as bright white lines (hyperechoic), poor reflectors produce darker shades of gray (hypoechoic), and fluid that does not reflect at all appears as black (anechoic). Higher-frequency waves create images with greater resolution; however, they are more rapidly attenuated with tissue penetration. A 10 MHz transducer cannot penetrate more than 5 cm into the parenchyma of a solid organ, such as the liver, and does not yield satisfactory images if applied transabdominally. Intraoperative ultrasound (IOUS) allows use of these higher-frequency high-resolution probes where abdominal wall thickness is not an issue. With higher-frequency probes directly on the surface of the organ, better images can be obtained, and smaller lesions often missed by computed tomography, magnetic resonance imaging, or transabdominal ultrasound can be found.

The IOUS was initially reported in the 1960s^{1,2}; however, it really gained importance with the advent of laparoscopic surgery. It gave another dimension to the tissue evaluation as the tactile feedback was lacking during the use of laparoscopy. Use of laparoscopic ultrasound (LUS) is more challenging and has a steeper learning curve, since ultrasound (US) transducers need to be introduced through a trocar and manipulated within limited space with limited range of motion. Different types of laparoscopic US transducers are available. The two most commonly used are the curved array and linear array transducers with an articulating head (Figure 44.1). With the inherent advantages of laparoscopic

surgery and the use of LUS, many procedures can now be completed laparoscopically in an accurate and safe manner.

LAPAROSCOPIC ULTRASOUND FOR STAGING LAPAROSCOPY IN PANCREATIC CANCER

Staging laparoscopy (SL) is used in many gastrointestinal cancers prior to laparotomy to confirm the resectability of the disease. With the availability of high-resolution multidetector computed tomography (MDCT), positron emission tomography-computed tomography, and magnetic resonance imaging scans, the sensitivity and specificity of staging a cancer preoperatively have greatly improved. However, limited assessment of local invasion, inability to identify small peritoneal metastasis, and inability to obtain tissue sample for confirming pathology for subsequent chemotherapy remain major drawbacks. SL has been found to be beneficial in avoiding unnecessary laparotomy in about 20%–30% of patients who are deemed resectable with preoperative imaging.^{3,4} Whether the addition of LUS in these patients adds any benefit in detecting any more unresectable cancers has been the subject of study, and the supporting evidence so far has been controversial and inconclusive. In a meta-analysis done in 2010,⁵ 26% of 2,827 patients were found to be unresectable who were initially deemed resectable on preoperative staging. In subgroup analysis, LUS further improved the sensitivity for detecting unresectable cancer. In a study published by the current author, 26% (7/27) of patients were found to be unresectable during SL, and three of them were identified due to LUS secondary to portal vein occlusion and metastases to the lymph nodes and liver not identified previously.⁶

Under general anesthesia and after carbon dioxide (CO₂) insufflation, an 11 mm port is placed through the umbilicus, and a 5 mm port is placed in the right upper quadrant.

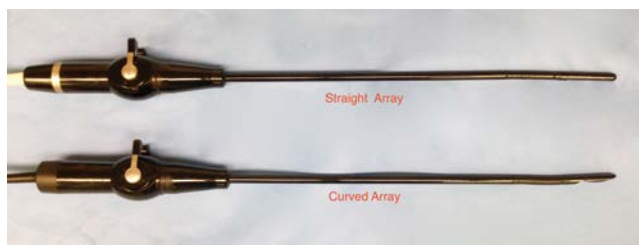


Figure 44.1 Laparoscopic ultrasound transducers.

Peritoneal and solid organ surfaces are inspected, including the pelvis, the root of the mesentery just below the transverse mesocolon, and all accessible viscera. Any surface lesion is biopsied, and a frozen section is obtained. In most cases, we do not attempt to enter the lesser sac. Washings are done after instilling 250 cc of normal saline. The fluid also helps as an acoustic interface for LUS images. The aspirate is sent for cytology at the end of the case.

A detailed LUS examination is then performed. An articulating probe is placed via the umbilical port under visual control with a 5 mm laparoscope. The hepatic parenchyma is scanned going from segment one to eight in both the longitudinal and transverse planes. Suspicious deep hepatic lesions are biopsied percutaneously with a Tru-cut needle under LUS guidance. LUS assessment of the entire pancreas, with attention to the primary tumor, is done through a transduodenal or transgastric window. The probe is used to compress the walls of the stomach to displace intraluminal air, thus providing an excellent acoustic interface. The tumor's characteristics, including size, echogenicity, and local extent, are noted. Its relationship to vascular structures, particularly the portal vein, mesenteric vessels, and hepatic artery, is sought. Color-flow Doppler is useful for identifying vascular structures. The pancreatic duct and bile ducts are inspected, and a thorough evaluation of the celiac artery, superior mesenteric artery, and suprapancreatic, periportal, and para-aortic lymphatic basins is done.

Ultrasound images of pancreatic cancer typically show a hypoechoic tumor with poorly defined borders and occasionally mixed echogenicity. Chronic pancreatitis due to pancreatic duct obstruction may demonstrate diffuse hypoechoic pancreatic parenchyma, which can obscure the visualization of a hypoechoic tumor or make the tumor margins difficult to define. Suboptimal US images may result from extensive intraperitoneal or pancreatic fatty tissue, which reduces penetration of the tissue. Vascular invasion of the portal vein or superior mesenteric artery is suggested if there are no visible tissue planes between vessel and mass. Liver metastases are usually well-circumscribed masses that appear hypoechoic, hyperechoic, or isoechoic with a hypoechoic halo. A lymph node that has an ovoid shape, hypoechoic rim, and isoechoic center may be larger than 1 cm and still be considered normal. Loss of nodal architecture may be indicative of metastasis. Pathologic nodes may be of any size, but they are always less well circumscribed and more hypoechoic and rounded.^{7,8}

ULTRASOUND FOR COLORECTAL LIVER METASTASIS

Colorectal liver metastasis (CRLM) presents a different type of challenge for preoperative staging. With improved chemotherapy, even extrahepatic disease is no longer an absolute contraindication for liver resection or ablation, provided complete resection of intra- and extrahepatic disease is feasible.^{9,10} Further, the patient with CRLM deemed unresectable, occasionally becomes a candidate for resection if he or she has good response to chemotherapy. The 5-year survival rate is similar to resectable disease.⁹ This impels us to conclude that accurate preoperative imaging would be essential before management of CRLM, since laparotomy and liver resection is still the treatment of choice for these tumors. Many national and international societies do not advocate routine use of SL and LUS for preoperative assessment of CRLM.^{9,11} However, a meta-analysis done to identify the role of SL with LUS identified 17% patients to be unresectable who were deemed resectable with imaging alone. This improved resection rates from 71% to 86%.¹²

In our practice, we have been able to identify many small liver lesions during LUS which were previously unidentified with imaging alone. Also, the relation of lesions with the surrounding vasculature is better delineated with the US. There is usually a gap of around 2 months between the last imaging study and surgery, during which the patient is off chemotherapy. Whether these lesions arise or advance during that time period or were missed in initial imaging studies would be difficult to ascertain.

LAPAROSCOPIC ABLATION OF LIVER TUMORS

Resection of malignant liver masses is a major surgery and is associated with significant morbidity and mortality. It still, however, remains the treatment of choice whenever possible. Many investigators have tried to use ablative techniques to treat these lesions in order to preserve the normal parenchyma and to decrease the overall morbidity. Two of the most commonly used ablation techniques are radiofrequency ablation (RFA) and microwave ablation. The principle of ablation lies in the fact that tissue heated above 60°C will die instantly due to protein denaturation, cell wall degradation, and microvascular thrombosis. RFA uses rapidly alternating current at ~450,000 Hz, and microwave ablation uses electromagnetic waves at 915 MHz or 2.14 GHz to cause an increase in temperature. The energy is delivered into the lesion through probes. To completely ablate the tumor, a 1 cm margin of normal parenchyma must also be ablated to prevent any failure and subsequent local tumor recurrence. These techniques have been used successfully laparoscopically using LUS for precise positioning of the probe in the optimal location for complete destruction of the lesion.

Ablation techniques are mainly used in the cases where either surgical resection is not possible or to preserve enough functional hepatic parenchyma.^{13,14} Its use as a primary

treatment modality is very limited, with our center being one of them. Most of the studies so far have used ablation percutaneously and usually for palliation.¹⁵ Visualization and accurate probe placement are limited by the percutaneous approach; hence, there is high local recurrence. This was demonstrated in a study where surgically placed RFA probes, either laparoscopic or open, were found to have superior results as compared to the percutaneous approach.^{16–18} So far there has been no large study or randomized control trial comparing laparoscopic RFA to open resection. With improving technology and greater experience by surgeons, laparoscopic and open ablation is gaining momentum among other modalities of treating malignant liver lesions with improved outcomes and decreased recurrence. The key to its success lies in the ability to accurately place the probe for optimal ablation. The critical components are accurate visualization with real-time ultrasound; greater access to difficult locations both open and laparoscopically; ability to displace bowel, diaphragm, and other vulnerable organs for surface lesions; and surgeon experience.

In our practice, most RFAs are done laparoscopically using an Angiodynamics enhanced water-cooled system, which is capable of producing up to a 7–8 cm ablation zone for treating lesions up to 6 cm. The US probe is inserted through a 10 mm port in the umbilicus, and a 5 mm laparoscope is inserted through a port in the right subcostal region. The liver is scanned thoroughly, and all the lesions are visualized and accurately measured. The relationship with major vessels, bile ducts, as well as adjacent viscera is carefully noted. The RFA probe is then inserted through the abdominal wall and into the liver in-line with the ultrasound probe from heel to toe so that the whole trajectory of the probe is visualized in real time. Once the probe is accurately placed, the lesion is slowly ablated at 105°C while gradually advancing the twines of the probe into the lesion for a uniform burn (Figure 44.2). The location of the twines can be visualized through the ultrasound; however, it is difficult to visualize the ablated tissue with ultrasound due to the presence of air bubbles. Visualization improves as the tissue cools down. The local ablation is limited by two factors: the size of the tumor and the proximity to the central bile ducts. Many reports in the literature have shown higher

recurrence rates with tumor size of more than 3 cm and ablation of more than three lesions.^{18,17} Furthermore, ablation near the hepatic hilum and major branches can cause severe complications such as bilomas, strictures, and portal vein thrombosis. Also, large veins near the lesions being ablated can cause a heat sink and cooling of the adjacent tissue leading to ineffective ablation.

USE OF LAPAROSCOPIC ULTRASOUND IN PANCREATIC NEUROENDOCRINE TUMORS

Pancreatic neuroendocrine tumors (pNETs) arise from islets of Langerhans. They are associated with increased hormone production in 10% of cases, and the rest are nonfunctional. The presenting symptoms of functional tumor depend on the hormone that is being overproduced. Among functional tumors, insulinomas are the most common followed by gastrinomas. Surgical resection when possible is the preferred treatment of choice. However, due to the benign and solitary nature of most of these tumors, especially insulinomas, enucleation has been advocated and performed in many of these cases. Various imaging modalities are available to identify the location preoperatively with varied success.¹⁹ Before the laparoscopic era, palpation of the pancreas could identify 80%–90% of these tumors.²⁰ IOUS increased this success rate to 95%–100%.¹⁹ With adaptation of the laparoscopic technique for pancreatic surgery, the use of LUS was a natural extension of the technique.^{21,22} LUS can identify the location as well as its relationship to pancreatic duct and major vessels, allowing one to assess the feasibility of the enucleation of the tumor.^{23,24} It is also helpful to guide the dissection in cases of spleen-preserving distal pancreatectomy, which remains technically very challenging due to the presence of many branches from splenic vessels to the pancreatic parenchyma.

LAPAROSCOPIC ULTRASOUND DURING CHOLECYSTECTOMY

With the adoption of laparoscopic cholecystectomy in the early 1990s, the rate of bile duct and vascular injuries had

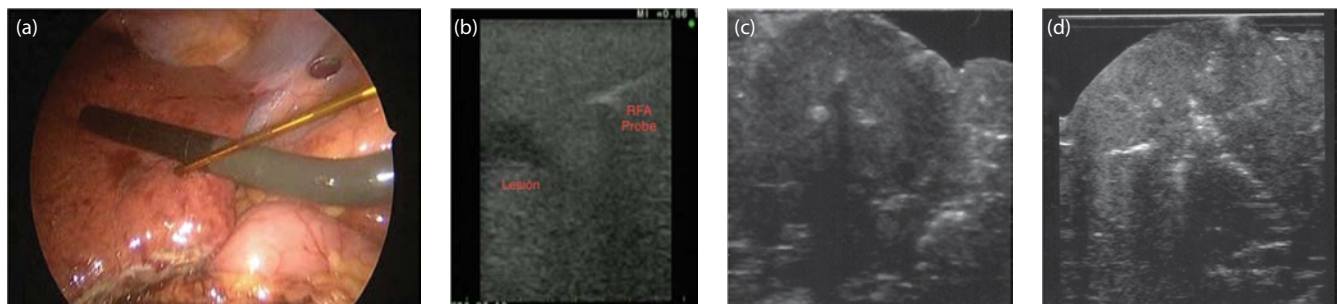


Figure 44.2 RFA of a liver lesion. (a) Note the parallel placement of RFA probe to the LUS. (b) RFA probe targeting the lesion. (c,d) Another lesion in transverse view. Note the central position of the probe along with its twines.

a threefold increase.²⁵ Since then, there has been a renewed interest in intraoperatively defining the anatomy as well as identifying common bile duct (CBD) stones. The two main modalities that are used are intraoperative cholangiogram (IOC) and LUS. Both are comparable in their success rates and their sensitivity and specificity toward identifying CBD stones.^{26–31} LUS has the distinct advantage of no radiation or contrast dye. This is useful for pregnant patients as well as those with iodine allergy, where IOC is contraindicated. The examination can be done repeatedly without the need for cannulation and possibly injuring the CBD if the biliary anatomy is misinterpreted during the initial dissection. Further, many studies have shown better timeliness and cost-effectiveness of LUS when compared to IOC.^{30,31,33,34} In a multicenter retrospective analysis of 1,381 patients in which our group participated, LUS was instrumental in preventing conversion to open procedure in 5.9% of the patients, where IOC was not possible due to unclear anatomy secondary to severe inflammation or anatomical anomalies.³²

We use a 10 mm umbilical port for US scanning during surgery, although others have also described scanning through the epigastric port. The surgeon stands on the right side of the patient and uses his or her right hand to maneuver the US probe and the left hand for the laparoscope, which is placed in one of the right subcostal ports. Both US and laparoscopic screens are on the right side of the patient, and an operating room circulating nurse helps with the US machine (Figure 44.3). US evaluation is usually done after dissecting the cystohepatic triangle. In cases with difficult anatomy, the US can be used to identify the landmarks for further dissection. The probe is placed in a longitudinal fashion on the liver, first directly over the segment 4b, just medial to the gallbladder. The depth and the frequency are now set to give the best time/gain settings. The probe is positioned to view the hepatic hilum. The portal triad is visualized in the longitudinal fashion, and lack of flow in the color Doppler is used to identify the common hepatic duct. This is then followed caudally with transhepatic views identifying the cystic duct and CBD junction and the supraduodenal part of the CBD. At the lower edge of the liver, the probe is then



Figure 44.3 Operating room setting to do the LUS.

placed parallel directly on the hepatoduodenal ligament, and the depth of the US image is readjusted. Again the CBD is followed longitudinally along its length while maneuvering the probe clockwise and counterclockwise to keep it in view. The supraduodenal, infraduodenal, and intrapancreatic portions of the CBD are visualized until the distal portion, which turns transversely, is now seen transversely joining the ampulla. The pancreatic duct is here seen joining the CBD before entering the ampulla. A note of any stone or narrowing in the extrahepatic biliary system is made, which is then confirmed in the transverse view. The probe is placed horizontally on the hepatoduodenal ligament, and the “Mickey Mouse view” is obtained with the CBD on the right, the common hepatic artery on the left, and the portal vein at the bottom (Figure 44.4). Again, the CBD is followed distally until it enters the duodenum. Sometimes the intrapancreatic view to identify distal CBD stones is difficult to obtain due to a fatty pancreas, which is a poor conductor of US waves.

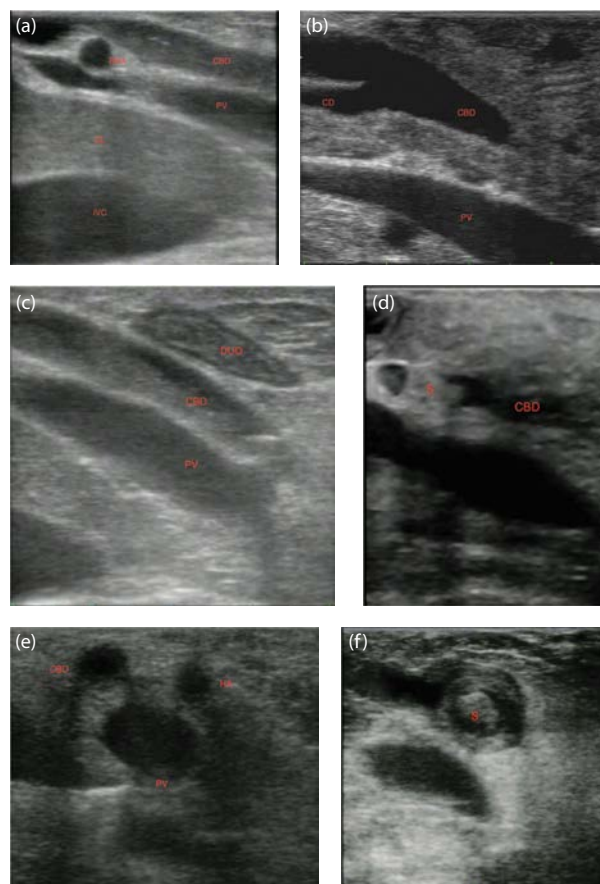


Figure 44.4 (a) Longitudinal infrahepatic view. (b) Cystic duct joining the CBD posteriorly. (c) Longitudinal retroduodenal view showing the CBD with sludge. (d) Stone in the CBD. (e) Transverse hepatoduodenal ligament “Mickey Mouse view.” (f) A nonshadowing stone in the ampulla. (CBD, common bile duct; CD, cystic duct; CL, caudate lobe; Duo, duodenum; HA, hepatic artery; IVC, inferior vena cava; PV, portal vein; RHA, right hepatic artery; S, stone.)

In those situations, a transduodenal view is obtained by placing the probe transversely against the lateral border of the duodenum in the second portion and pressing medially against the ampulla, which helps in identifying the distal CBD, which can be followed cranially.

Although having been shown to be extremely safe and reproducible, the use of LUS is hampered secondary to lack of training in residency programs, as well as development of new imaging modalities with higher resolution. Understanding its role, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) published the guidelines for utilizing LUS in 2009. There is a steep learning curve for LUS. No specific numbers of cases for training have been recommended by any society; however, different authors have omitted their initial 20–100 cases of LUS in publications to indicate their learning curve.²⁷ Nevertheless, with the increasing use of minimally invasive techniques for doing complex surgical procedures, the need to inculcate the LUS in surgical practice has never been greater.

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Three-dimensional printing development and medical applications

FEROZE MAHMOOD AND DANIEL B. JONES

INTRODUCTION

Three-dimensional (3D) printing is a form of additive manufacturing that is based on creating tangible customized 3D models of desired objects.¹ Unlike volumetrically rendered 3D images on screens that create a perception of depth rather than actual depth, 3D printed models are devoid of this parallax error. Affordable desktop 3D printers can feasibly generate models in a variety of materials with a vast range of stiffness and density. Also, 3D printers can use multiple materials to generate composite models. The health care–related applications of 3D printing are just beginning to be explored.^{2,3} They range from creating customized instruments, patient-specific models of anatomy for education, task training, and simulation. Finally, the potential of bioprinting to generate vascularized solid organs has been demonstrated as well. A decade ago 3D printing was a research technique; it is now a viable clinical technique.

INVENTION AND DISCOVERY PHASE

The process of 3D printing, also known as stereolithography (STL), is a technology invented by Charles Hull in March 1983.⁴ His research at Ultraviolet (UV) Products in California focused on using UV light to harden UV-curable resin. Charles Hull used this technology to cure photopolymer resin in layers creating a plastic-eyewash ([Figure 45.1](#)), the first object ever printed using this technology. He patented the technology and co-founded 3D Systems in 1986; a company that is currently among the world leaders in the field of 3D printing. From being exclusive to research and industrial uses, various commercial companies have produced affordable desktop consumer–level 3D printers

([Figure 45.2](#)). The applications of 3D printing continue to evolve from the printing of complex industrial machines to everyday consumer products. There is exponential interest in medicine-related applications of 3D printing. This has ranged from generating patient-specific dental implants to anatomical models for procedural planning and task training. With the availability of 3D printers capable of printing in composite sterilizable materials, the role of 3D printing in medicine is likely to increase ([Figure 45.3](#)).

The process of 3D printing involves progressive deposition of layers of materials to generate a solid model.⁵ Printers differ in their design in composing the deposition of layers; printers with adaptive processes are able to calculate the most accurate method of laying down layers so that neither



Figure 45.1 The first 3D printed object was a small cup that was meant to be used as an eyewash by Charles Hull in 1986.

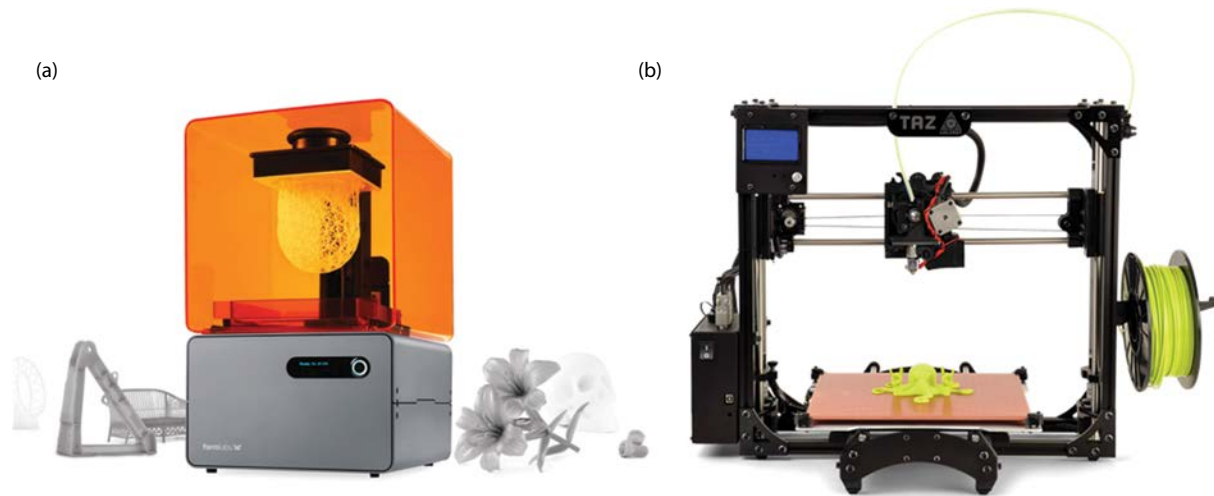


Figure 45.2 Affordable desktop 3D printers range from the (a) form 1+ that uses STL and the (b) TAZ Lulzbot 5 utilizing FDM.



Figure 45.3 Stratasys Objet30 Prime uses sterilizable materials to 3D print objects that can potentially be used as surgical adjuncts in the future.

time nor materials are wasted. Aside from hardware changes, software modifications are also apparent. With the addition of higher processing power, stereolithography (STL) files are now more accurate and have higher resolution, allowing high fidelity and larger size prints.⁶ Though the basic technology architecture that makes it possible to print 3D objects has not changed, individual processes have been modified to greatly increase the capabilities of 3D printers.

3D PRINTING TECHNOLOGIES

The four most popular are stereolithography (STL), selective laser sintering (SLS), a technique known either as fused deposition modeling (FDM) or fused filament fabrication (FFF), and inkjet 3D printing. Each process confers its own specific advantages and disadvantages, and as such, all have slightly different applications depending on their intended use.

Stereolithography

Stereolithography relies on an UV laser to cure a photopolymer resin. As the laser traces out a pattern in the liquid resin, the resin hardens into the desired shape. When a layer is complete, the bed of material moves down by one increment, as small as 0.025 mm, so that a small layer of liquid resin rests on top of the layer that has already been cured. The process repeats, layer by layer, until the entire 3D print is finished. After this process, the 3D printed object is cleaned with a mixture of chemicals and requires exposure in an UV oven to optimize its texture and hardening. The advantages of STL are the accuracy of the finished product and the complex geometries that can be printed. Depending on the quality and amount of the photopolymer, it can be a costly method, and it is a comparatively time-consuming 3D printing process, with complicated prints taking more than a day to complete.

Selective laser sintering (SLS)

This technique is similar to STL in that it uses a laser to harden material into the desired shape. It differs in that the material used for 3D printing with SLS technique is typically a plastic powder. In addition to plastic, it is possible to use the same technique with powdered metal. Use of metal powder for 3D printing is specifically known as direct laser metal sintering (DLMS). In both SLS and DLMS, the top layer of the bed of powder is sintered into the desired shape, and subsequently, the bed of powder is lowered by about 0.1 mm, and a new layer of powder on top of the first layer is sintered.⁷ The excess powder deposition provides mechanical support during the printing process, negating the need for external supports. This allows more complex geometries to be printed. One of the main advantages of this technique is that multiple materials and objects can be printed; printers are not limited to just

plastic. The accuracy of this method is moderate compared to other printers. The final product in SLS usually has excess powder and grit post-printing and sometimes requires extra finishing steps. The materials used in SLS are usually inexpensive, but the cost of energy to create the object is high. An inkjet 3D printing technique uses a powder bed, similar to SLS.

Fusion deposition modeling (FDM)

The technique of FDM uses a nozzle laying down a liquid plastic, which hardens after exposure.⁸ Layers of plastic are built sequentially creating the 3D object. This method of printing is relatively inexpensive and the least time consuming. Because of the nature of extrusion of plastic and change in its stiffness, the models are not of the highest fidelity. It is one of the most popular techniques used for desktop 3D printing for hobbyists.

Inkjet printing

An inkjet head, similar to that of a conventional two-dimensional (2D) printer, sprays down a liquid that binds the powder together in the geometry of the desired object.⁹ A layer of powder is brushed over the top of the first layer, and the printer sprays another layer of the binding agent. This technique is fast and has the cosmetic benefit of allowing the object to come in a medley of different colors and thicknesses.¹⁰ Multiple materials are available for use with this method, including ceramic, starch, and sugar. Inkjet printers are relatively inexpensive, fast, and produce high-resolution models. They are also very diverse in material choices for 3D printing.

CURRENT STATUS OF MEDICAL 3D PRINTING

Dental surgery

There have been numerous applications of 3D printing in the field of dental medicine. Patient-specific anatomical dental models have been used as task trainers and as adjuncts for surgical planning. Commercially available anatomical training models are expensive, lack high fidelity, and are not reusable. High-fidelity patient-specific teaching models of dental anatomy can be feasibly printed using various materials.¹¹ These 3D printed models are not only useful for trainees but also have value as patient education tools.¹¹ These 3D printed dental models have also been used as surgical task trainers to facilitate acquisition of proficiency by the trainees.¹² Besides education and procedure planning, patient-specific dental implants have been 3D printed for clinical use, e.g., a metallic patient-specific “root-analog implant” was 3D printed using direct laser metal sintering technology for implantation (Figure 45.4).¹³ Dental hardware made with 3D printing technology has the benefits of being customizable to a patient’s unique anatomy and of



Figure 45.4 3D printed, patient-specific “root analog” implant.

being less expensive than traditional custom-made implants and other dental necessities (Figure 45.5).

Plastic and reconstructive surgery

3D printing of patient-specific anatomical models has demonstrated value as task trainers and as a procedure-planning adjunct in plastic surgery. Specifically for reconstructive procedures involving facial and skull bones, 3D printed models of patient’s skull derived from scanning have been used to plan/modify procedures based on the peculiarities of the anatomy (Figure 45.6).¹⁴ In one study, patient-specific drilling guides were 3D printed to enhance accuracy and precision with a more aesthetically pleasing end result.¹⁵ In another study, a rib graft was printed to correctly shape rib cartilage for facial reconstructive surgery.¹⁵



Figure 45.5 3D printed stainless steel dental caps are examples of customizable, cheaper alternatives to traditionally used dental materials.

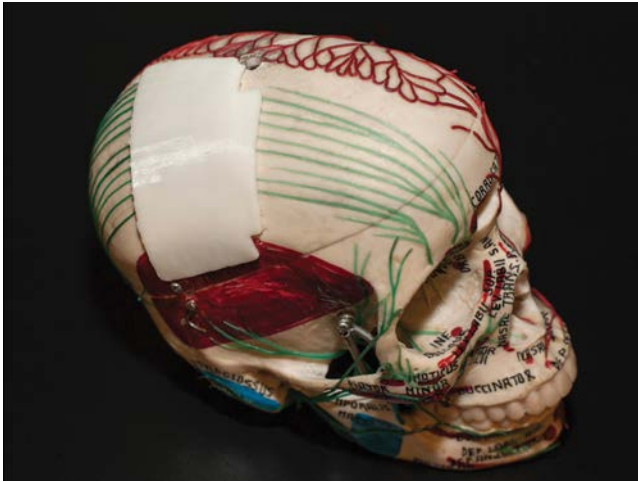


Figure 45.6 Patient-specific 3D printed skull plates can be used to guide a cranioplasty.

Orthopedic surgery

As in other health care-related fields, 3D printing is used for modeling of patient-specific anatomical prints to assist in procedure planning.¹⁶ Specifically for knee replacement surgery, high-fidelity 3D prints of a patient's knee are used to generate molds to manufacture patient-specific metallic implants (**Figure 45.7**). 3D printing has also been used to grow bone tissue through seeding of cells on anatomical scaffolds.^{17,18}



Figure 45.7 3D printed model of the knee from data derived from computed tomography scans. (© Nevit Dilmen.)



Figure 45.8 Models of normal and abnormal mitral valves made by using 3D echocardiographic data.

Cardiac surgery

Cardiac surgical applications of 3D printing have steadily increased.^{19–24} Use of real-time echocardiographic data for 3D printing of intracardiac structures has gained particular interest as surgical planning adjuncts^{25–27} (**Figure 45.8**). Flexible 3D printed models of heart valves and great vessels have also been deployed in pulsatile chambers to assess hemodynamics of native and prosthetic valves.^{19,28}

Thoracic surgery

Clinical applications of 3D printing for thoracic surgical procedures involve 3D printing of lung and chest wall tumors and their vascular structure for assistance in incision planning and defining resection margins (**Figure 45.9**).²⁹ Use of a 3D printed bioabsorbable stent has been reported for an intractable case of tracheobronchomalacia.³⁰ Patient-specific models of thoracic and lumbar spine have been printed to create task trainers for epidural catheter placement and spinal surgery (**Figure 45.10**).³¹

Vascular surgery

In vascular surgical interventions, endovascular aortic procedures have demonstrated promise in deriving value from 3D printing. Patient-specific models of aortic aneurysms have been printed and used as guides for physician modification and fenestration of endovascular grafts (**Figure 45.11**).^{32,33} This is likely to reduce operation time, radiation exposure, and dye load during endovascular procedures.

Surgical education

Whereas virtual volumetric renditions of anatomy can be generated on flat screens, they are not tangible and lack

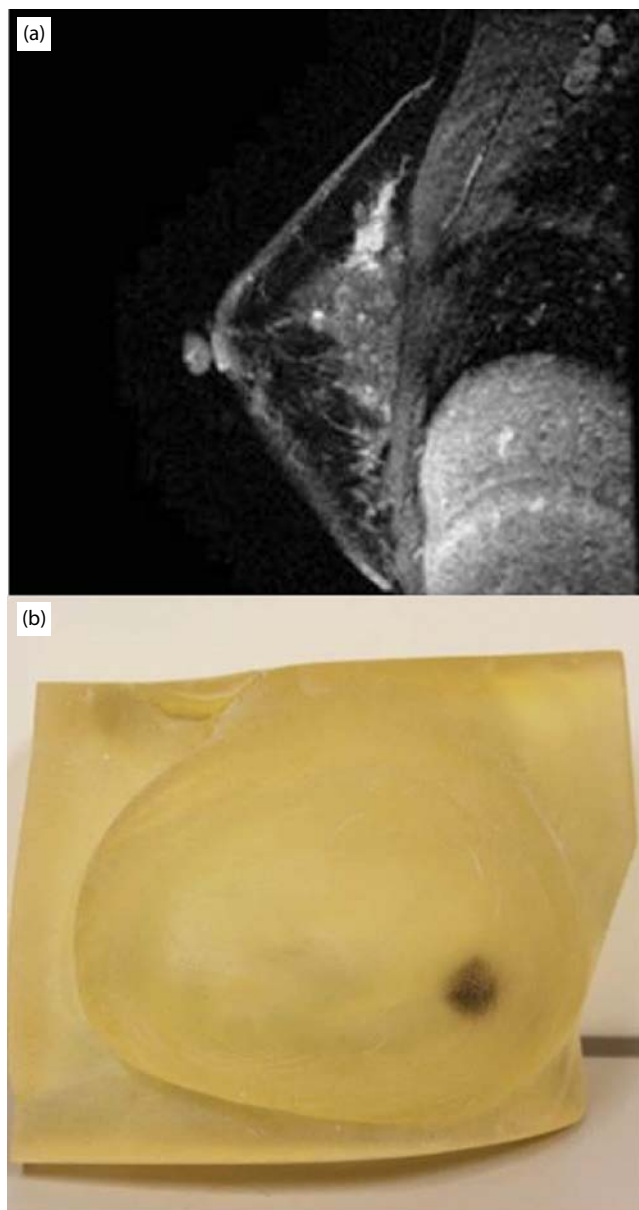


Figure 45.9 (a) Sagittal T1 fat-saturated contrast-enhanced image showing enhancing irregular lesion within the upper quadrant of the breast. (b) Model of the left breast with the dark irregular lesion representing possible malignancy.

haptic feel. With enhanced spatial orientation, there is enhanced appreciation of the complexities of anatomy with possibly improved learning (Figure 45.12). Volumetric data acquired from a various imaging modalities can be used to generate STL files for 3D printing (Figure 45.13).¹

FUTURE OF 3D PRINTING

3D printing is an exciting technology with an ever-expanding repertoire of indications. Specifically for health care, the value of 3D printing keeps increasing with the

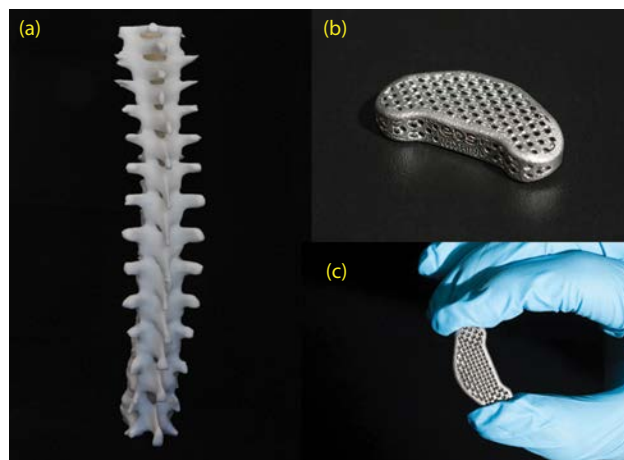


Figure 45.10 3D printing has been used to create patient-specific task trainers for (a) epidural placement and (b and c) 3D printed titanium spinal disc replacements for degenerative disc disease treatment.

quality of and sophistication of printers. Surgical instruments, implants, and anatomical models can now be 3D printed in sterilizable materials. Whereas we are far from customizing clinical implants for patients, the technology exists to achieve these clinical breakthroughs. Bioprinting of tissues is another exciting application of 3D printing using living cells as the building components of solid tissues (Figure 45.14).³⁴ With this technology, researchers have been able to create sheets of living cells, as well as tubular cellular structures.³⁵ Printing of vascularized functional solid organs for transplantation is within the realm of possibilities. Seeding of 3D printed anatomical scaffolds with living cells is another exciting application. The scaffold provides the shape for the cells to grow in, and after time, the scaffold would be absorbed into the cells.¹⁸ With 3D printers becoming affordable, their everyday use will increase exponentially. It is likely that with technological innovations, the “image to print” time will be significantly reduced, and 3D printing will be used in a point-of-care fashion.

CONCLUSION

Rapid prototyping or 3D printing technology has created a paradigm shift in how surgeons interact with patients in explaining their disease process, discussing management options, and obtaining informed consent. When confronted with difficult operations due to complex anatomy, the operative approach can be practiced on the model. Intraoperatively, a real-sized model can be used as a reference and arguably is more useful than any clinical imaging modality in conceptualizing anatomical relationships. Specific instruments and implants can be manufactured and tailored to the patient’s unique needs. For vascular

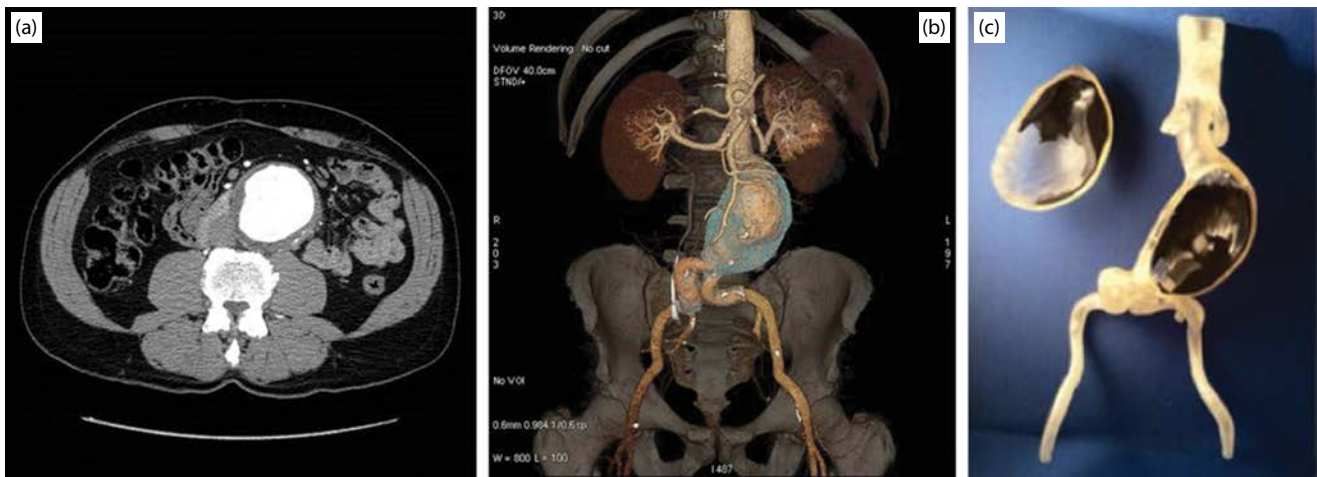


Figure 45.11 (a) 2D contrast-enhanced axial computed tomographic image of abdominal aortic aneurysm. (b) 3D reconstruction of aortic aneurysm. (c) Model of aneurysm with translucent outer aorta wall that has been sectioned in the coronal plane to reveal internal anatomy with the calcifications in white and mural thrombus in black.



Figure 45.12 (a) Axial multidetector computed tomographic contrast-enhanced delayed image of cholangiocarcinoma with vague area of enhancement within the hepatic hilum (black arrows) along with associated marked intrahepatic biliary dilation. (b) Complete liver tumor model before painting. (c) Model of liver tumor and vasculature only (painted) showing tumor mass.



Figure 45.13 3D printed model of abdominal aortic aneurysm derived from magnetic resonance imaging data.



Figure 45.14 Three-dimensional bioprinter, capable of printing live organs, as designed by 3D Bioprinting Solutions.

stents, no longer does one size fit all. Whether in the simulation center or the operating room, 3D printing is forcing surgeons to rethink preoperative counseling, practicing on models, and intraoperative possibilities.

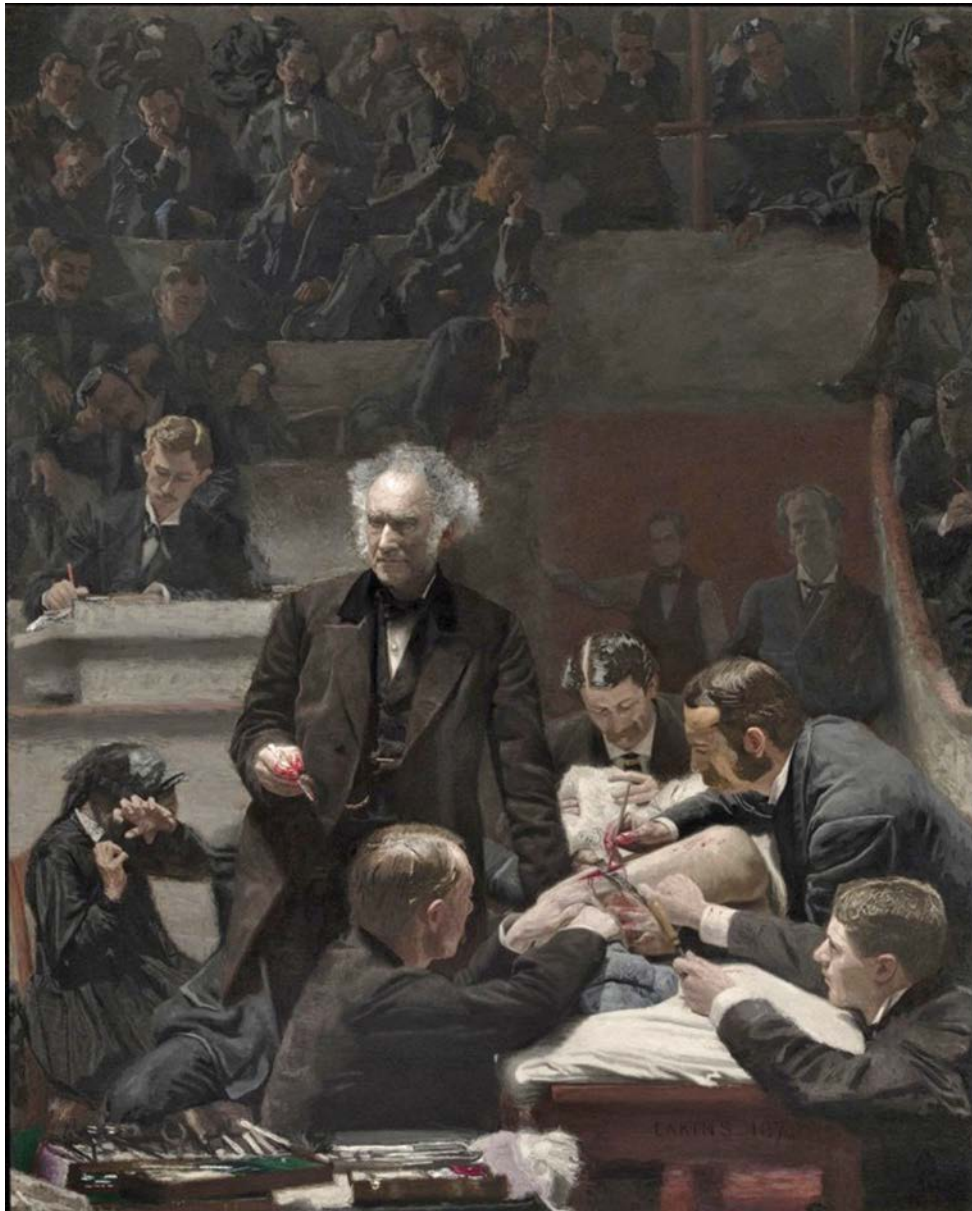
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Minimally invasive treatment of esophageal disease



Thomas Eakins, *Portrait of Dr. Samuel D. Gross (The Gross Clinic)*, 1875. Oil on canvas, 8 x 6 1/2 feet. Gift of the Alumni Association to Jefferson Medical College in 1878 and purchased by the Pennsylvania Academy of the Fine Arts and the Philadelphia Museum of Art in 2007 with the generous support of more than 3,600 donors, 2007.
(Artwork in the public domain; image courtesy the Philadelphia Museum of Art.)

Samuel Gross (1805–84) was co-chair of the Department of Surgery at Jefferson Medical College from 1882 to 1889 and author of a standard surgical textbook. Here, he performs surgery for osteomyelitis, in a procedure that does not incorporate the antiseptic technique recently developed by Joseph Lister—Gross said, “Little faith is placed by any enlightened surgeon on this side of the Atlantic in the so-called carbolic treatment of Lister.” The surgeon stands apart from the others in a heroic presentation that depicts the nineteenth-century American ideal of pragmatism, which held that heroism is earned by what you do rather than inherited as part of who you are. In this case, heroism is represented by the surgeon’s scalpel rather than by something like a king’s crown.

Thomas Eakins attended many of Dr. Gross’s lectures on anatomy, surgery, and orthopedics, and had been present at scenes like this, sitting with the rows of students watching and taking notes in the amphitheater. When the city of Philadelphia hosted the 1876 Centennial Exhibition, with the major themes advertised as advancements in American science and art, Eakins submitted this painting, which satisfied both fields. However, it was rejected by the jury selecting for the art pavilion because it did not satisfy Victorian ideas of what art should be: there was visible blood; the operating

room was considered no place for a woman; the tones were too dark; and the bright spots that did exist drew attention to more horror—the pink towel to the surgical instruments and the blue socks to the bloody incision. Dr. Gross intervened, and the painting was shown in the exposition—in the US Army Post pavilion with displays of modern medical equipment and techniques.

Dr. Gross was one of the first to present lectures on morbid anatomy in the United States, and in 1839 he published his second text called *Elements of Pathological Anatomy*, which went through three editions. In 1867, he served on a committee that passed a resolution of the College of Physicians in Philadelphia calling for the state to pass the Anatomy Act of Pennsylvania. Gross was a founder of the American Medical Association and founder and first president of the American Surgical Association.

Quotation from James M. Edmonson, American Surgical Instruments (Novato, CA: Norman Publishing, 1997), 71.

Text by Dr. Linda Pessar and Mariann Smith, courtesy Center for Medical Humanities, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo.

Anatomic and physiologic tests of esophageal function

JOEL M. STERNBACH AND ERIC S. HUNGNESS

INTRODUCTION

Esophageal function testing includes an array of endoscopic, radiologic, and catheter-based diagnostic studies used in the evaluation of common upper gastrointestinal tract symptoms. Manifestations of esophageal disease prompting such investigation include heartburn, dysphagia, regurgitation, noncardiac chest pain, as well as extraesophageal symptoms such as globus or cough.

UPPER ENDOSCOPY

Esophagogastroduodenoscopy (EGD), or upper endoscopy, is often used as a first-line test in the evaluation of esophageal transit symptoms, such as dysphagia or regurgitation, to rule out a structural or obstructive etiology prior to additional testing. These include infiltrating tumors, external compression from vascular or other sources, peptic strictures, and esophageal rings or webs. In addition to the above, EGD allows the diagnosis of diseases based on direct examination of the mucosa or pathologic studies of endoscopic biopsies, including erosive esophagitis, infectious esophagitis, eosinophilic esophagitis, pill or caustic injury, Barrett esophagus, and the presence of foreign bodies. The assessment of esophageal anatomy on EGD is generally limited to a qualitative evaluation, such as noting the presence of a large or small hiatal hernia, a “tight” lower esophageal sphincter (LES), and a general assessment of motility (absent, tertiary contractions, spasm, etc.).

BARIUM ESOPHAGRAM

Despite the introduction of tests with higher-resolution axial imaging (computed tomography [CT]), modalities that do not require exposure to ionizing radiation (magnetic

resonance imaging [MRI]) and those that provide quantification of metabolic activity for the detection of malignancy (fluorodeoxyglucose-positron emission tomography CT [FDG PET-CT]), barium esophagram (BE) remains a simple but critical tool in the evaluation of esophageal anatomy and function. The vast array of radiographic techniques, imaging, and contrast administration protocols that are subsumed under the generic term “upper GI” can be a source of confusion and potentially result in suboptimal evaluation of symptoms.

Video swallow

The oropharynx and proximal esophagus are optimally evaluated in conjunction with a speech and swallow therapist during the performance of a “video fluoroscopic swallow study,” also known as a “modified barium swallow.” During the study, patients swallow a variety of substances ranging from thin-barium to radiopaque cookies, providing an unparalleled functional evaluation of the swallowing mechanism, detection of clinically “silent” aspiration events, and delineation of oropharyngeal anatomy. This combination of anatomic and functional evaluation is ideal for identifying structural pathology as a source of symptom generation, including Zenker diverticula or cricopharyngeal bars, as well as purely functional conditions, such as oropharyngeal dysphagia after stroke.

Esophagram

The anatomy and gross motility of the esophageal body are visualized during a single- or double-contrast esophagram. The former refers to the administration of thin barium alone, a study typically reserved for the evaluation of a tracheoesophageal fistula or Schatzki ring, and preceded

by the administration of an effervescent contrast agent in assessing the latter. Double-contrast studies allow detailed visualization of the mucosa, while single-contrast studies provide quantification of the diameter of the esophagus, particularly areas of stricture.¹ Multiple swallows, with the patient in a variety of positions (anteroposterior, oblique, supine, upright, etc.), are visualized by the radiologist performing the exam. A “cine” esophagram involves the acquisition and storage of video rather than still images during the study.

Functionally, findings on BE and high-resolution manometry (HRM) tend to correlate well in terms of peristaltic efficacy and velocity,² with distal esophageal emptying becoming increasingly dysfunctional at peristaltic pressures below 30 mm Hg. Due to the nature of the study, BE provides a more physiologic evaluation of flow through the esophagus and particularly at the level of the esophago-gastric junction (EGJ) than HRM.³ The ability to vary the characteristics of the contrast agent can allow targeted evaluation of specific symptoms, such as solid-food dysphagia or the likelihood of food impactions in patients unable to pass a 12.5 mm solid barium tablet.^{4,5}

Qualitative evaluation of mild to moderate gastroesophageal reflux during BE has been inconsistent; however, gross reflux to the level of the thoracic inlet has been shown to correlate with abnormal results on ambulatory pH tests.⁶ Additional findings on BE that are suggestive of gastroesophageal reflux disease (GERD), but lack diagnostic specificity, include a “patulous” EGJ, presence of distal esophageal strictures, or identification of a large hiatal hernia.^{7,8} The sensitivity of BE for the diagnosis of GERD can be as low as 34%.⁹ BE does provide a distinct advantage over endoscopy in the identification of the type and size of hiatal and paraesophageal hernias, including the relationship of the hernia to the diaphragm and relative position of the EGJ.

BE also has an important role in the evaluation of post-fundoplication dysphagia, allowing detection of wrap disruption, a “slipped” or herniated wrap, and functional obstruction at the level of the fundoplication (iatrogenic EGJ outflow obstruction). During evaluation of refractory reflux symptoms, BE can accurately identify patients with scleroderma esophagus; a patulous and dilated esophagus is characteristic of the disease process, which is a contraindication to fundoplication. Additional uses of BE include the diagnosis and surgical planning for Zenker diverticula and epiphrenic diverticula and visualization of midesophageal pulsion or traction diverticula (Figure 46.1).

Diseases resulting in esophageal stricture are also excellent candidates for assessment with BE, including the unique mucosal pattern seen in eosinophilic esophagitis (EoE), the strictures or narrow-caliber characteristic of esophageal involvement in patients with lichen planus, and the length and degree of stricture in patients following caustic ingestion. In the latter group, video fluoroscopic studies offer a critical assessment of oropharyngeal function when considering esophageal resection. Long-segment esophageal injury secondary to nasogastric tube

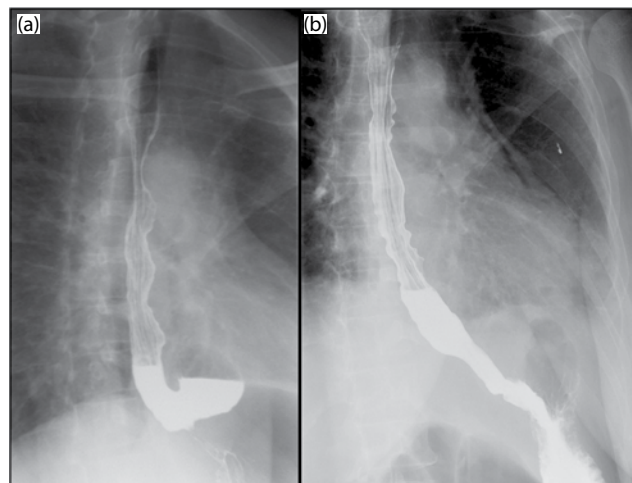


Figure 46.1 Barium esophagram in the evaluation of esophageal disease. Examples of barium esophagram from a patient with a history of hypertensive lower esophageal sphincter (a) before and (b) after laparoscopic hiatal hernia repair, epiphrenic diverticulectomy, and Heller myotomy with Dor fundoplication.

trauma, although less common than in the past, is also visualized well on BE and can help guide the choice of therapeutic intervention (dilation versus stent versus esophagectomy).

Timed barium esophagram

Endoscopy can occasionally be normal in patients with achalasia⁹; however, BE is highly sensitive for esophageal dilation and the smooth tapering or “bird-beak” appearance of a nonrelaxing LES. More specific protocols, such as the timed barium esophagram, have been shown to be superior to symptom evaluation in predicting the need for reintervention in patients with achalasia undergoing pneumatic dilatation.¹⁰ During timed barium esophagram, a known volume of barium (typically 200 mL) is consumed, and the height and width of the column that forms above the EGJ is measured (in cm) at 1, 2, and 5 minutes (Figure 46.2).¹¹

HIGH-RESOLUTION MANOMETRY

Manometry provides an evaluation of esophageal motor function in patients with symptoms unexplained by EGD or contrast studies. The introduction of catheters with solid-state pressure transducers and subsequent development of high-resolution manometry (HRM) catheters greatly enhanced the performance and interpretation of manometric studies over the traditional water-perfused systems (Figure 46.3).

Common uses of HRM include the localization of the LES prior to placement of pH or pH-impedance catheters,

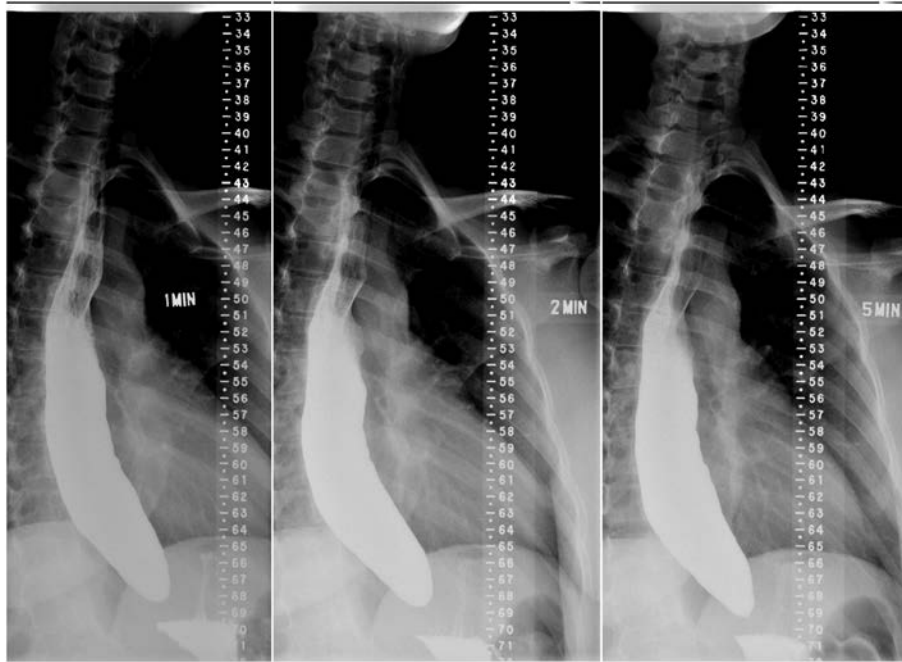


Figure 46.2 Timed barium esophagram. The classic “bird-beak” appearance of a nonrelaxing lower esophageal sphincter in a patient with type I achalasia and significant stasis are evident at 1, 2, and 5 minutes after ingesting 200 mL of barium.

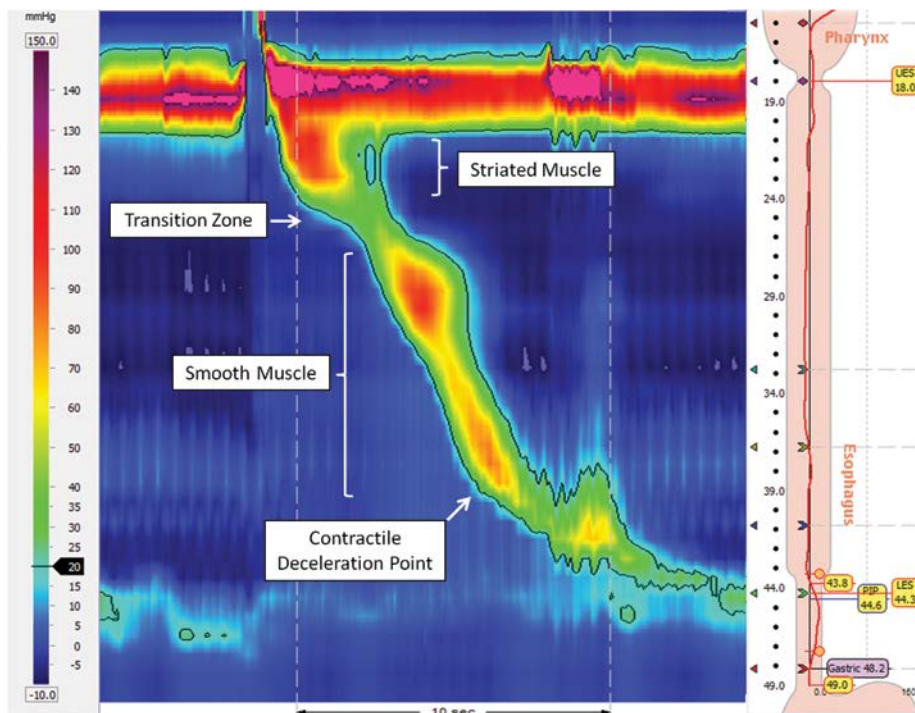


Figure 46.3 Esophageal pressure topography (Clause) plot highlighting the components of a single, normal swallow with an intact peristaltic wave progressing caudally. Time is on the x-axis, length along the esophagus on the y-axis and the color gradient on the left depicts higher pressures in red and lower pressures in blue. The solid bands at the top and bottom of the image represent the upper esophageal sphincter (UES) and lower esophageal sphincter (LES), respectively. (PIP, pressure inversion point.)

assessment of peristaltic function prior to antireflux surgery and in the diagnosis of esophageal motility disorders. The latter includes primary peristaltic disorders, with or without EGJ outflow obstruction.¹²

Contraindications to catheter-based studies generally involve an inability to safely pass the testing device through the naso- and oropharynx, along the thoracic esophagus and past the EGJ into the stomach. These include abnormal anatomy or obstructing tumors of any of the previously mentioned structures as well as uncorrectable coagulopathy or an inability to cooperate with the examination.

The study is conducted by a trained manometry technician on a conscious patient, although placement of the catheter can be performed during sedated endoscopy in those patients unable to tolerate the procedure. Ten swallows of 5 mL of saline are performed in the supine position with the head of the bed elevated 10°–15°. Additional swallows are often performed in the upright position, particularly in patients at significant risk for aspiration.¹³

A variety of HRM metrics assist in the classification of motility disorders, including characterization of the LES (mean inspiratory and expiratory pressure as well as the 4-second integrated relaxation pressure [IRP]) and evaluation of peristaltic vigor (distal contractile integral [DCI]), speed (distal latency), and integrity (20 mm Hg isobaric contour). Threshold measurements can vary depending on the technical specifications of the manometry system used. Normal mean values used as references for the Chicago Classification include the following¹⁴:

- IRP <10 mm Hg^{15,16}
- DCI 450–5000 mm Hg/cm/s (<450 = ineffective swallow, >8000 not encountered in healthy controls and is used to define jackhammer esophagus)^{12,17}
- DL >4.5 seconds (<4.5 seconds = premature and characteristic of spastic motility disorders)¹⁸
- Breaks in the 20 mm Hg isobaric contour >5 cm = fragmented peristalsis, a condition that is frequently symptomatic.¹⁹

INTERPRETATION OF RESULTS

The results of manometric evaluation of the esophagus should be utilized in the context of complementary diagnostic modalities, particularly anatomic evaluation with barium swallows or EGD. The identification of EGJ outflow obstruction on manometry should prompt further investigation (radiographic versus EGD ± endoscopic ultrasound) to rule out an infiltrative process.

The presence of outflow obstruction as measured by an abnormally elevated IRP and disordered or absent peristalsis is diagnostic of achalasia. The Chicago Classification, originally described by Pandolfino and colleagues,²⁰ and now in its third iteration,¹² provides a clinically relevant classification of achalasia subtypes based on the pattern of peristalsis

in the esophageal body. Those patients with pan-esophageal pressurization during swallows (type II achalasia) have consistently been shown to have significantly better response to disruption of the EGJ by either surgical myotomy or endoscopic pneumatic dilatation. These patients are theorized to be at an earlier stage in the progression toward complete aperistalsis (type I achalasia) and progressive dilation of the esophageal body. Premature contractility characterizes a minority of patients (type III or spastic achalasia) who more frequently present with chest pain rather than classic transit symptoms and have historically been more difficult to treat with therapy directed at the lower esophageal sphincter²¹; more recently, promising results have been obtained in this patient population by performing an extended proximal myotomy during peroral endoscopic myotomy (POEM).²² Similarly, other hypercontractile disorders such as distal esophageal spasm (DES) and jackhammer esophagus, often presenting with chest pain with or without dysphagia, have been successfully treated with an extended myotomy in those patients refractory to medical therapy with smooth muscle relaxants or PDE5 inhibition.²³

HRM can also demonstrate the esophageal shortening and nondeglutitive decrease in tone that occur during transient lower esophageal sphincter relaxation (TLESR) events. TLESRs have been shown to be a common mechanism of reflux, usually induced by gastric distension.²⁴ An increased frequency of TLESRs, in association with increased intragastric pressure, is thought to contribute to both pregnancy-induced and obesity-related GERD. Pandolfino and colleagues²⁵ compared HRM evaluation of the EGJ in 75 asymptomatic controls and 156 patients with GERD, finding the latter to have reduced LES pressure and larger separation between the LES and crural diaphragm. That impaired function of the crural diaphragm was the strongest predictor of GERD.

Currently, manometric evaluation of the esophagus is a standard component of the preoperative evaluation in patients planning to undergo fundoplication for the treatment of GERD. In addition to providing a baseline documentation of motility function, against which postoperative studies can be compared, manometry can identify “named” esophageal disorders, including scleroderma esophagus and achalasia, that are contraindications to complete 360° fundoplication.²⁶

Compromised peristaltic function has been associated with higher rates of dysphagia in patients undergoing a 360° Nissen fundoplication during laparoscopic antireflux surgery, although this has been debated.²⁷

AMBULATORY PH MONITORING

Given the multiple disease processes that can lead to reflux symptoms, routine ambulatory pH monitoring has become a standard component of the evaluation prior to antireflux surgery, particularly in patients without endoscopic evidence of reflux (Los Angeles grade C or D esophagitis, Barrett esophagus, etc.).

The increasing burden of obesity and rising incidence of reflux disease in the population have fueled significant investment in diagnostic testing modalities for GERD, resulting in the availability of a variety of catheter-based and wireless systems. Following an overnight fast, catheter-based systems (either traditional dual-channel 24-hour pH monitoring or multichannel intraluminal impedance pH monitoring) are placed transnasally and positioned 5 cm above the proximal extent of the manometrically identified LES. Alternatively, a wireless, capsule-based sensor (Bravo, Given Imaging Ltd., Yoqneam, Israel) can be affixed to the mucosa 6 cm proximal to the squamocolumnar junction (SCJ) during endoscopy, with pH data sampled every 6 seconds and transmitted to an external recording device worn by the patient for 48–96 hours.

Patients are instructed to keep a diary of meal times, supine positioning, and episodes of reflux symptoms as well as to avoid overly acidic beverages, minimize snacking, and consume only water between meals. With the exception of evaluation for non-acid reflux, most ambulatory pH studies are done with the patient off of proton pump inhibitors for a minimum of 7 days and H₂-blockers for at least 3 days. Using catheter-based studies, a drop in measured pH in the distal esophagus to below 4 is considered to represent acid reflux.

Johnson and DeMeester²⁸ laid out a systematic approach to esophageal pH monitoring more than 40 years ago, providing reference values based on asymptomatic controls and describing the DeMeester score, a six-parameter composite scoring system to quantify distal esophageal acid exposure that is still in use today. The components of the DeMeester score are total, upright, and supine esophageal acid exposure times, as well as the total number of episodes of reflux, number of reflux episodes lasting more than 5 minutes, and duration of the longest reflux episode. Applying individual weighting to the six factors, a DeMeester score greater than 14.72 or total acid exposure time greater than 4.2% of the study are considered abnormal results indicating the presence of pathologic GERD.

Additional prognostic value has been derived by correlating patient-reported symptoms to episodes of objectively measured reflux. Commonly used and referenced indices include the symptom index (SI), the symptom sensitivity index (SSI), and the symptom association probability (SAP). The percentage of subjective reflux events associated with reflux is known as SI,²⁹ with an SI greater than 50% considered clinically elevated. Conversely, the SSI is calculated as the percentage of symptoms associated with reflux episodes.³⁰ The SAP was subsequently developed to better incorporate the total number of reflux episodes and is based on a 2 × 2 contingency table of symptoms and reflux events.³¹

In patients with typical symptoms of GERD, a positive pH-monitoring study is highly predictive of symptomatic relief following antireflux surgery.³² Alternatively, those patients with endoscopic evidence of erosive esophagitis but

a negative ambulatory pH test have been shown to respond poorly to surgical management.³³

MULTICHANNEL-INTRALUMINAL IMPEDANCE

Multichannel-intraluminal impedance (MII) can be performed independently, as a catheter-based assessment of bolus transit, but is more commonly performed in conjunction with pH monitoring (MII-pH or pH-impedance testing) or esophageal manometry (MII-EM or HRIM). The basic principle of MII involves using variation in the resistance to flow of an alternating current between two electrically isolated metal ring electrodes to determine the substance surrounding the catheter. Air, with its relatively low ionic concentration, has a high impedance value as a reference. Esophageal mucosa has a baseline impedance between 2000 and 3000 ohms; during a swallow, the passage of a liquid bolus is observed as sequential decreases in impedance between pairs of electrodes from the mouth to the stomach (**Figure 46.4**).

The main indication for MII-pH testing is in the evaluation of PPI nonresponders, in whom non-acid reflux may be detected and correlated with periods of patient-reported symptoms. Studies have shown rates of symptomatic non-acid reflux in up to 40% of these patients.³⁴

The results from preoperative combined MII-pH monitoring results for 19 patients undergoing Nissen fundoplication showed 94% of patients with a positive SI had complete resolution of reflux symptoms postoperatively, while two patients with negative SI had recurrent reflux symptoms.³⁵ However, other studies have not found differences in symptomatic relief after Nissen fundoplication using MII-pH.^{36,37}

More recent studies utilizing MII-pH data to investigate GERD pathophysiology have led to the development of novel metrics including the postreflux swallow-induced peristaltic wave index, which indicates the efficacy of esophageal clearance, and utilization of baseline impedance levels to more accurately differentiate pathologic reflux disease from functional heartburn.³⁸

The combination of MII and manometry has provided new tools in the evaluation of dysphagia in fundoplication patients, both before and after surgery.³⁹ An automated impedance manometry system has been recently evaluated and used to develop a dysphagia risk index (DRI) as a method of predicting patients at risk for the development of postfundoplication dysphagia.⁴⁰

The incorporation of impedance ring electrodes between pressure sensors along manometry catheters has allowed detailed assessment of bolus transit in relation to pressure measurements using HRIM. Recently described HRIM metrics include impedance bolus height at 5 minutes, correlating well to traditional measurements requiring fluoroscopy during timed barium esophagram⁴¹ and bolus-flow time.⁴²

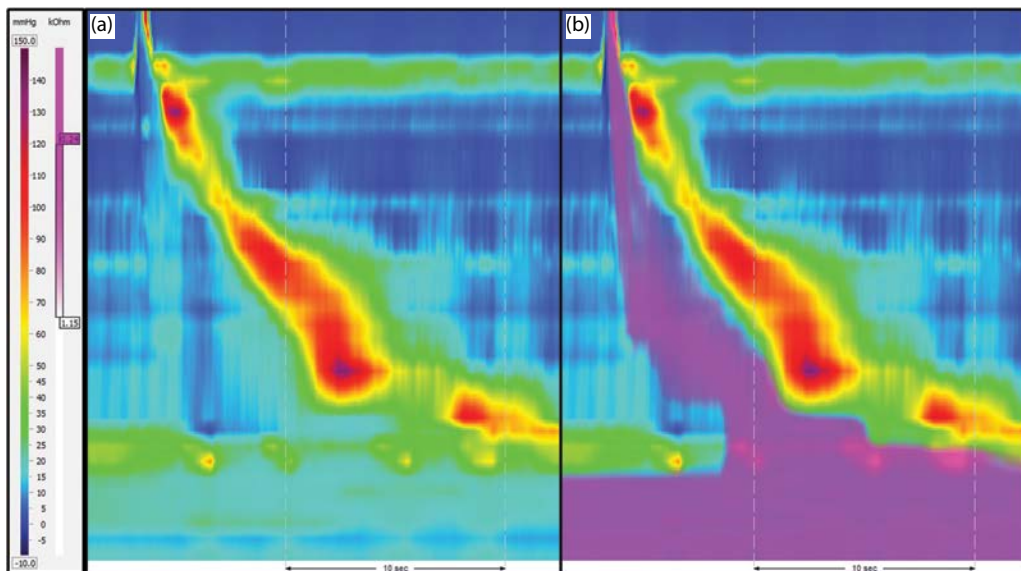


Figure 46.4 High-resolution impedance manometry study showing a normal swallow both as (a) a standard esophageal pressure topography plot and (b) with impedance data overlay. The presence of a liquid bolus is demonstrated by an abrupt decrease in impedance, shown as purple coloring, that is subsequently cleared by the peristaltic wave.

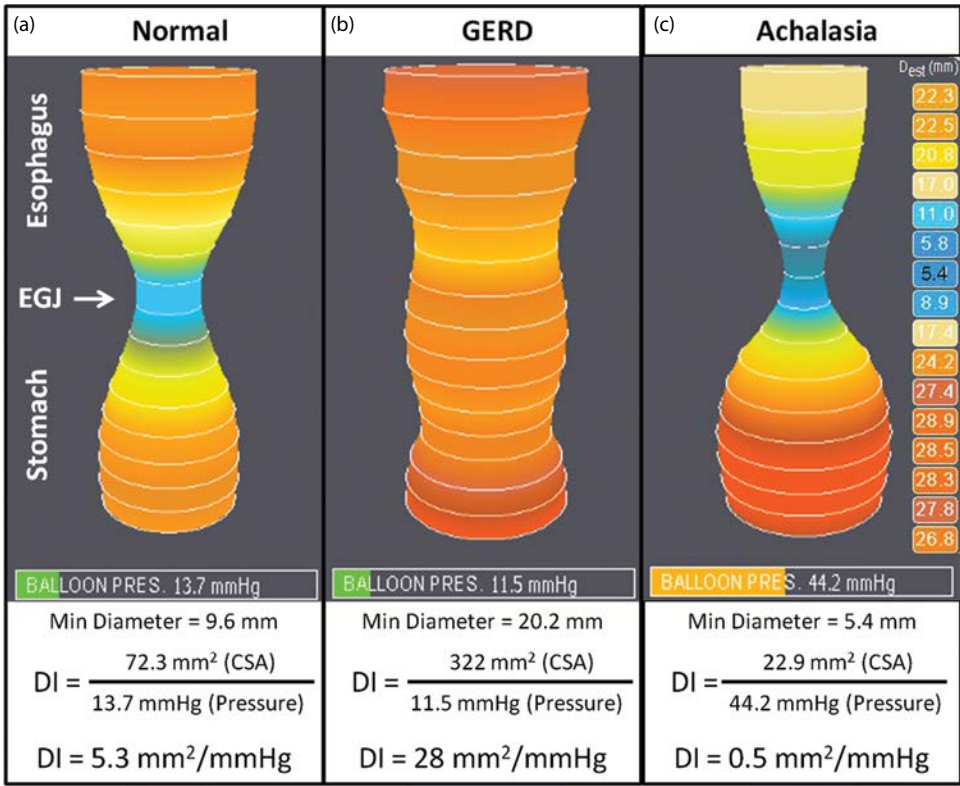


Figure 46.5 Functional lumen imaging probe studies of the esophagogastric junction (EGJ) utilizing impedance planimetry. The distensibility index (DI) is calculated as the minimum cross-sectional area at the level of the EGJ divided by the intraballoon pressure. Study images and quantitative analysis show clear differences in (a) an asymptomatic control, (b) a patient with gastroesophageal reflux disease (GERD) and an elevated DI, and (c) a patient with type II achalasia, showing a pathologically reduced DI.

IMPEDANCE PLANIMETRY

The functional lumen imaging probe (FLIP) is a commercially available (EndoFLIP, Crospon Ltd, Galway, Ireland), catheter-based system that provides a geometric evaluation of luminal structures by measuring 16 adjacent cross-sectional areas while simultaneously recording intraballoon pressure using a solid-state pressure transducer. When placed across the EGJ, dividing the minimum cross-sectional area by the intraballoon pressure allows a calculation of the distensibility index (DI) of the EGJ (**Figure 46.5**).

The use of FLIP in the diagnosis of achalasia and evaluation of treatment outcomes has been studied extensively.^{43–45} Kwiatek and colleagues also compared FLIP measurements of the EGJ DI in GERD patients and asymptomatic controls and found GERD patients to have a two to three times more distensible EGJ.⁴⁶

Recent studies have further evaluated the ability of intraoperative FLIP measurements to predict outcomes during a variety of foregut surgeries for both GERD and esophageal motility disorders.^{47,48} Eventually, FLIP may allow real-time calibration, allowing individualized tailoring of functional surgeries such as fundoplication and Heller myotomy, with the goal of optimizing postoperative outcomes.^{49,50}

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360° Fundo

PATRICK REARDON

INTRODUCTION

In the mid to late 1990s, we were performing laparoscopic 360° fundoplication following the technique described by DeMeester.¹ We were utilizing a traction suture placed in the posterior aspect of the fundus to assist in performing a true 360° fundoplication (**Figure 47.1**). The benefits of this technique have been previously described.² Choosing the exact, correct point for placement of this traction suture,

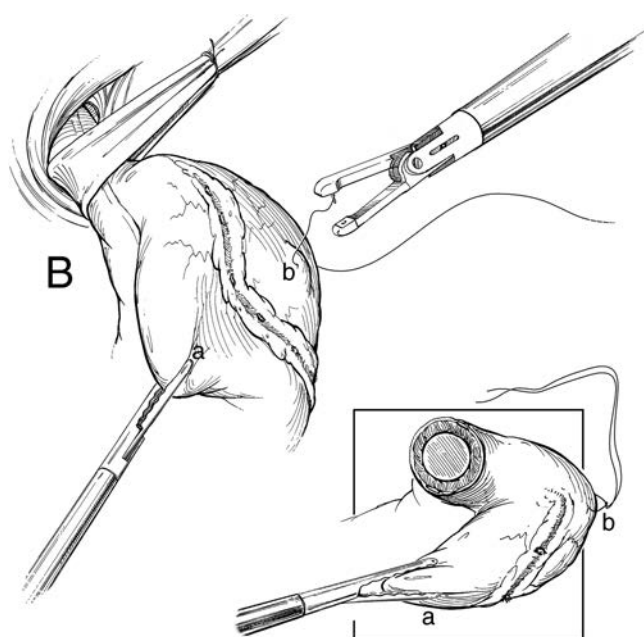


Figure 47.1 A traction suture, placed into the posterior fundus, ensures that it is the posterior fundus that is brought around posteriorly to form the right side of the fundoplication.

however, still required judgment borne of experience. Our current technique evolved from an effort to define exactly where that suture should be placed, in order that less experienced surgeons might be able to create reproducible, true, and proper 360° funduplications much earlier in their learning curves.

In order to understand the precise location of the points on the anterior and posterior fundus which should be brought together anteriorly to create a true and precise 360° fundoplication, we utilized “bench work” on fresh cadaver specimens. From fresh cadavers undergoing autopsy, we obtained a portion of the gastrointestinal tract including the entire esophagus, the stomach, and proximal duodenum. A 60 Fr Bougie was passed through the esophagus and into the stomach. The operation was then created, exactly as described by DeMeester.¹ The index finger was utilized to “dunk” the esophagus into the nontwisted fundus, and the index finger was left between the Bougie-filled esophagus and fundoplication (**Figure 47.2**) during its creation, to ensure adequate “looseness,” as we have previously described and illustrated.³ At each point at which the vertical suture utilized to create the fundoplication entered or exited through the stomach, we marked the stomachs with indelible ink. The operations were then deconstructed, and the locations of the points were measured in relation to a fixed landmark. That landmark was the junction of the left side of the distal esophagus and the origin of the greater curve. The points were noted to create an equilateral triangle measuring 6 cm per side (**Figure 47.3**), as we previously published.³

We followed up this study by measuring the esophageal circumference while a 60 Fr Bougie was in place, utilizing a flexible plastic ruler, in 250 consecutive adult patients undergoing laparoscopic hiatal hernia repair, 360° fundoplication, or both. The esophageal diameter was then calculated from the measured circumference. Multiple linear

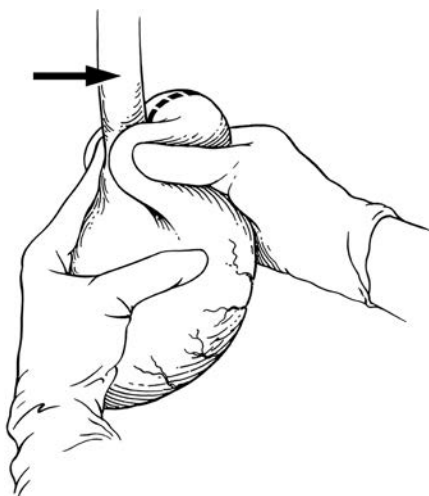


Figure 47.2 During open surgery to create a 360° fundoplication, the greater curve is cupped in the palm of the right hand. The left hand is used to “dunk” the esophagus into the nontwisted fundus. This creates a symmetrical, nontwisted fundoplication and maintains the proper orientation of the greater curve, relative to the fundoplication.

regression analysis was then used to predict the esophageal diameter from patient characteristics. The relationship can be defined by the regression equation:

$$c = [6.172 + (\text{age} \cdot 0.00849) + (\text{BSA} \cdot 0.813)]$$

The diameter of the 60 Fr Bougie-filled esophagus can then be calculated: $\text{Diameter} = c/\pi$. The inner diameter of the completed fundoplication = Calculated diameter of 60 Fr Bougie-filled esophagus + Additional length (AL). This “additional length” determines the looseness

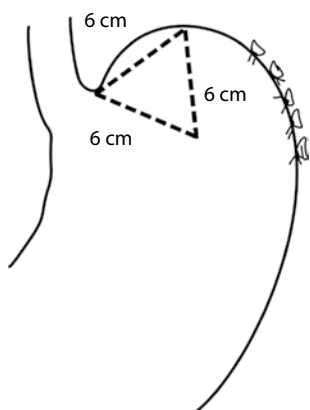


Figure 47.3 The distance from the junction of the distal esophagus and greater curve to the traction point on the greater curve was noted to be equal to the distance from the traction points on the anterior and posterior fundus to the junction of the distal esophagus and greater curve and creates an equilateral triangle.

or tightness of the completed fundoplication. The inner circumference of the completed fundoplication is calculated: $c = d \cdot \pi$. One-half of the inner circumference of the completed fundoplication = Calibrating suture length (CL) (Figure 47.4a–c).

Preoperatively, we enter the patient’s height, weight, and age into a calculator app (Figure 47.5) that then calculates the length of the distance representing one-half of the inner circumference of the completed fundoplication for AL values of 12 mm (loose), 9 mm (medium), and 6 mm (tight). We use this information to guide the “calibration” of the tightness of our fundoplication. A 0-silk suture is tied to the end of a slotted grasper and cut to the predetermined calibrated length (CL). Over the years, we have both tightened and lengthened our fundoplications. We now utilize an anterior length of 2.5 cm for our fundoplications and wrap all but the most severe forms of esophageal dysfunction using an AL of 6 mm, resulting in

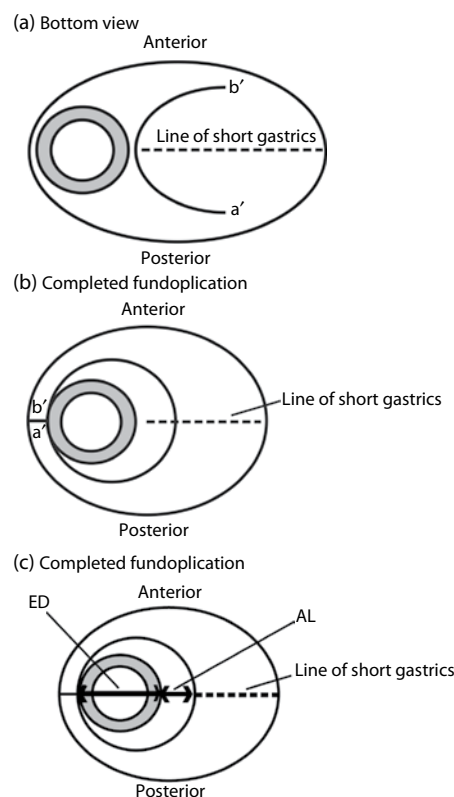


Figure 47.4 (a) The relationship of the anterior traction point (a') and posterior traction point (b') to the short gastric vessel stumps along the greater curve is depicted in a cranial to caudal view. The length of the line connecting points a' and b' will be the inner circumference of employed fundoplication. (b) When points a' and b' are pulled around to meet anteriorly on the esophagus, 180° opposite the native location of the short gastric vessels, a properly oriented 360° fundoplication results. (c) The inner circumference of the completed fundoplication is equal to the external diameter of the Bougie-filled esophagus (ED) plus some additional length (AL) to provide “looseness.”

Patient values	
Height (in.)	68.0
Weight(lbs.)	184.9
Age(yrs.)	63
BSA	1.98
BMI	28.17
Esophageal circ (cm)	8.32
Esophageal diam (cm)	2.65
Suture length loose (cm)	6.0
Suture length medium (cm)	5.6
Suture length tight (cm)	5.1

Figure 47.5 The patient's height in inches, weight in pounds, and age in years are entered into a calculator app. The length of the measuring suture needed to provide the location of the anterior and posterior traction points needed to result in "loose," "medium," and "tight" fundoplication are calculated and displayed. Additional patient biometric data are calculated. These include the body surface area (BSA), body mass index (BMI), and calculated circumference and diameter of the patient's esophagus if a 60 Fr Bougie were in place. We use the calculated esophageal diameter to determine the final anterior-posterior diameter of our closed hiatus.

our "tight" calibration. We use the calculated esophageal diameter to determine the final anterior-posterior diameter of our closed hiatus.

TECHNIQUE

All of the described techniques are from the perspective of a right-hand-dominant surgeon.

Trocar placement

Novices and those who prefer liver retraction systems use the following (**Figure 47.6**): one 12 mm and four 5 mm trocars.

The liver is retracted with a flexible liver retraction device via the right upper quadrant 5 mm trocar site.

The 12 mm trocar allows the use of a suturing device, such as the Endo Stitch device, which may make suturing easier for less-experienced surgeons.

More-experienced surgeons may use the following: four 5 mm trocars (**Figure 47.7**).

As surgeons gain more experience with the procedure and/or for surgeons who have acquired good laparoscopic suturing skills, this setup diminishes the number of trocars used and eliminates the suturing device, leading to a cost savings and some diminution in morbidity. When using a four-port approach, a suture is passed through the

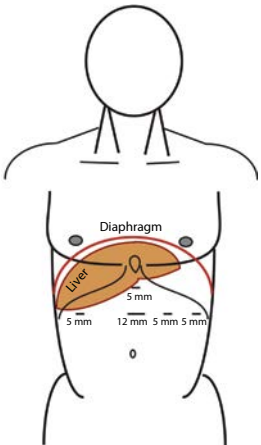


Figure 47.6 Trocar placement for novices and those who prefer liver retraction systems. One 12 mm and four 5 mm trocars. The liver is retracted with a flexible liver retraction device via the RUQ 5 mm trocar site. The 12 mm trocar allows the use of a suturing device, such as the Endo Stitch device, which may make suturing easier for less-experienced surgeons.

diaphragm just anterior to the right crus. Using a small, subxiphoid incision, the suture is then pulled up with one end externalized to the right side of the falciform ligament and one end externalized to the left side of the falciform ligament. We utilize this configuration to retract the liver in most of our patients.

Tip—The visualization trocar should be placed in the supraumbilical midline, about 11 cm below the xiphoid. Many surgeons are used to using the umbilicus as a port

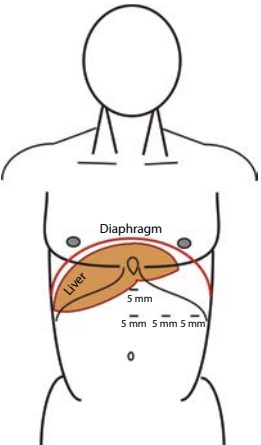


Figure 47.7 For more-experienced surgeons, four 5 mm trocars may be used. As surgeons gain more experience with the procedure and/or for surgeons who have acquired good laparoscopic suturing skills, this setup diminishes the number of trocars used and eliminates the suturing device, leading to a cost savings and some diminution in morbidity. When using a four-port approach, we utilize a suture passed through the diaphragm to retract the liver, as described in the text.

placement site. This should be avoided in most antireflux operations. Low camera trocar placement makes it difficult to visualize and work in the posterior hiatus and mediastinum.

The esophagus should be completely mobilized to allow for 3 cm of esophagus within the abdomen without any traction. The hiatus is closed. We divide the short gastric vessels, completely, up to the left crus. The fundus is freed of all attachments, posteriorly, from the starting point of mobilization of the greater curve to the posterior junction of the left and right crura. Care should be taken to spare all of the lesser curve vasculature and mesentery, medially. We perform an upper endoscopy on all patients at the completion of esophageal mobilization and reduction of any hiatal hernia. This allows us to correlate the location of the squamocolumnar junction with the anatomic distal esophagus, as identified by the junction of the linear smooth muscle fibers of the distal esophagus with the serosa-lined stomach at the origin of the greater curve. Some chronic gastroesophageal reflux disease patients will have a dilated, flared open distal esophagus that is not tubular. This morphology may cause it to be mistaken for the proximal stomach if careful inspection is not carried out.

The surgeon stands on the right side of the patient and the assistant on the left during creation of the fundoplication. The surgeon's left hand (SLH) utilizes a smooth, atraumatic, grasping instrument. The surgeon's right hand (SRH) starts with the same atraumatic type of grasper. The assistant holds the camera in the left hand and the slotted grasper (SG), with the calibrating suture (CS) tied to its end, in his or her right hand.

The junction of the distal left esophagus and the proximal greater curve (EGJ) is carefully identified. We identify the junction of the linear smooth muscle fibers of the distal esophagus with the serosa-lined stomach at the origin of the greater curve. The free end of the CS is grasped with the SLH. It is placed at the junction of the esophagus and greater curve, and firmly maintained in this position. The SRH grasps the greater curve, 7 cm distally, and rolls it medially and gently stretches it inferiorly. When the greater curve has been pulled gently tight, the SG is gently pulled inferiorly, maintaining a position just above the greater curve, until the CS is pulled taught. The SG is then moved posteriorly to grasp the greater curve. The grasping point of the SG will now be a distance from the EGJ equal to CL. The SG is then used to pull the greater curve anteriorly, inferiorly, and to the right until the greater curve has gently been stretched tight from the slotted grasper to the EGJ (Figure 47.8). The posterior fundus is gently pulled flat by the SRH. The free end of the calibrating suture is then rotated down onto the posterior fundus until it visually appears to be at a point that creates an equilateral triangle with its apices at the free end of the CS, SG, and the EGJ (Figure 47.9). The free end is released at this point, and the SRH is used to grasp the posterior fundus just posterior to the free end of the CS. The fundus is then gently stretched posteriorly, until it is tight. The location on the

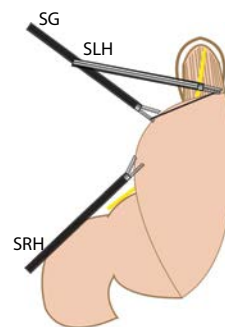


Figure 47.8 The surgeon's right hand (SRH) grasps the greater curve 7 cm distally, rotates it medially, then gently stretches the greater curve in an inferior direction. (The rightward rotation is exaggerated in this illustration, for clarity.) The surgeon's left hand holds the free end of the calibrating suture at the junction of the distal left esophagus and proximal greater curve. The assistant gently places inferior traction on the slotted grasper (SG) until the calibrating suture is pulled taught, maintaining a position just above the greater curve. The SG is used to grasp the greater curve at this exact point, with the jaw that anchors the suture on the posterior side of the fundus. The SG is then used to pull the greater curve anteriorly, inferiorly, and to the right until the greater curve has gently been stretched tight from the slotted grasper to the EGJ.

posterior fundus where the free end of the CS now lies is the point where the traction suture will be placed. This point is grasped by the SLH.

Using the SRH, a suture is placed into the posterior fundus at the point being grasped by the SLH, tied, and cut long (Figure 47.10). This will be a traction suture (TS), so the bite should go into the submucosal layer, but not be full thickness. This suture is cut long so that after the posterior fundus has been pulled over to the right side, if it is released for any reason, the suture will remain present on the right side to easily pull it back over for creation of the fundoplication.

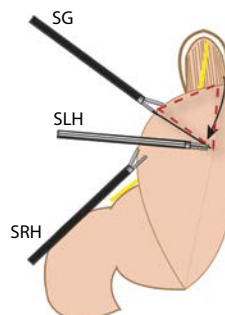


Figure 47.9 The posterior fundus is gently pulled flat by the SRH. The free end of the calibrating suture is then rotated down onto the posterior fundus until it visually appears to be at a point that creates an equilateral triangle (dashed red lines) with its apices at the free end of the CS, SG, and the EGJ.

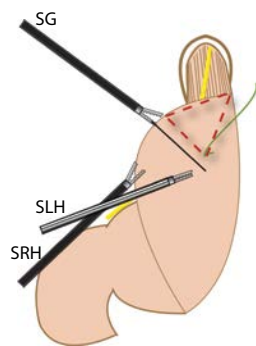


Figure 47.10 The free end is released at this point, and the SRH is used to grasp the posterior fundus just posterior to the free end of the CS. The fundus is then gently stretched posteriorly, until it is tight. The location on the posterior fundus where the free end of the CS now lies is the point where the traction suture will be placed. This point is grasped by the SLH. (Not depicted.) Using the SRH, a suture is placed into the posterior fundus at the point being grasped by the SLH, tied, and cut long.

The free end of the TS is then placed at the posterior, inferior aspect of the left crus.

Without changing its location on the greater curve, the slotted grasper is then rotated 180° until the arm where the suture is anchored is now on the anterior fundus. The greater curve is then retracted laterally, inferiorly, and to the patient's left by the SG, until the anterior fundus is pulled flat (**Figure 47.11**). The SRH is used to help flatten the anterior fundus. The SLH is used to pull the free end of the CS onto the anterior fundus to a point that appears to create an equilateral triangle whose apices are at the free end of the CS, SG, and the EGJ (**Figure 47.12**). The free end is released at this point, and the SRH is used to grasp the anterior fundus just medial to the free end of the CS. The fundus is then gently stretched medially, until it is tight. The location on the anterior fundus where the free end of the CS now lies is the point where the anterior traction suture will be placed. This point is grasped by the SLH.

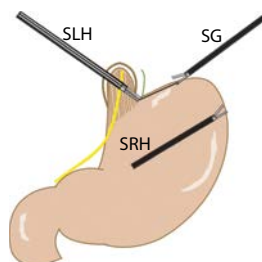


Figure 47.11 Without changing its location on the greater curve, the slotted grasper is then rotated 180° until the arm where the suture is anchored is now on the anterior fundus. The greater curve is then retracted laterally, inferiorly, and to the patient's left by the SG, until the anterior fundus is pulled flat.

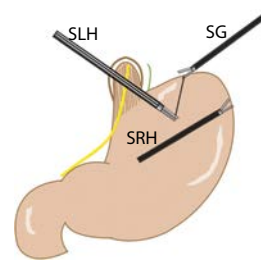


Figure 47.12 While maintaining the position of the SRH and the SG, the SLH is used to rotate the calibration suture down onto the anterior fundus until it visually appears to create an equilateral triangle.

Using the SRH, a suture is placed at this point, tied, and cut short (**Figure 47.13**). Except for the traction suture being cut short, the process is exactly analogous to the way the posterior traction suture point is chosen. The two traction points that will be used to create the fundoplication have now both been established.

Viewing posteriorly, from right to left behind the gastro-esophageal junction (GEJ), the posterior traction suture is grasped and used to pull the posterior fundus behind the GEJ and over to the right side. As soon as the point is visible where the suture originates on the posterior fundus, the fundus itself should be grasped at this point. Manipulation of the fundus by direct grasping is safer, as using the suture to apply traction may cause it to pull through if too much traction is applied. The anterior, or left-sided traction point is now also grasped. A confirmatory “shoe-shine” maneuver is carried out (**Figure 47.14**). The short gastric vessel stumps should be located posteriorly, halfway between the two traction points.

The two traction points represent the points for placement of the lowest sutures in the fundoplication. We utilize pledgeted U-stitches of 0-braided polyester sutures for all but the superior-most suture. Pledgets placed on the superior-most suture may rotate cranially and contact the esophagus, which should be avoided.

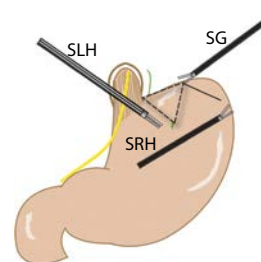


Figure 47.13 The SRH is then used to provide traction medial to the end of the suture. At the point where the end of the suture comes to rest, a suture is placed, tied, and cut short. Except for the suture length, the process is exactly analogous to the way the posterior traction point is chosen.

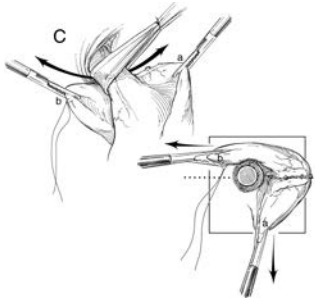


Figure 47.14 Viewing posteriorly, from right to left behind the GEJ, the posterior traction suture is grasped and used to pull the posterior fundus behind the GEJ and over to the right side. The anterior, or left-sided traction point, is now also grasped. A confirmatory "shoe-shine" maneuver is carried out. The short gastric vessel stumps should be located 180° posteriorly, halfway between the two traction points.

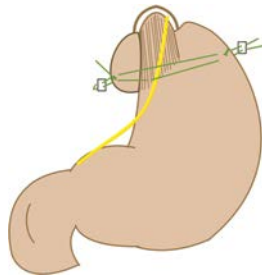


Figure 47.15 The path of the first suture, which is pledgeted, is depicted. The suture passes through the esophagus to the right of the anterior vagus nerve. The suture is then tightly tied.

The path of the first suture is as follows (**Figure 47.15**):

1. Through the left-sided pledget.
2. Through the left-sided traction point.
3. Through the distal esophagus, to the right of the anterior vagus nerve, at the 10 o'clock position. (The entry and exit points of esophageal bites should be no more than 2 mm apart to avoid excessive narrowing of the esophagus when the suture is tied.)
4. Through the right-sided traction point.
5. Through the right-sided pledget.
6. Back through the right, then left-sided traction points, 3–4 mm apart, inferiorly, from the first bites of the suture through the inferior fundoplication.
7. Back through the left-sided pledget, and tied.

The second suture is the superior-most suture and is non-pledgeted, as described. The path of the second suture is as follows (**Figure 47.16**):

1. Through the superior-medial left side of the fundoplication, 2.5 cm superior to the first suture.
2. Through the esophagus, to the right of the anterior vagus nerve, 2.5 cm superior to the first suture.

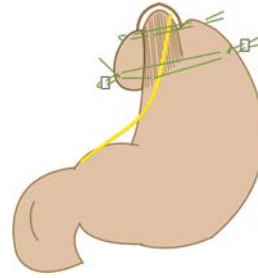


Figure 47.16 The path of the second suture, which is not pledgeted, is depicted. This suture is placed 2.5 cm above the first suture. The suture passes through the esophagus to the right of the anterior vagus nerve. Once this suture is tightly tied, the anterior length of the fundoplication is set, and is 2.5 cm.

3. Through the superior-medial right side of the fundoplication, 2.5 cm superior to the first suture.
4. Back through the right, then the left side of the fundoplication, 3–4 mm apart, superiorly, from the first bites of the suture through the superior fundoplication, and tightly tied.

The fundoplication calibration and anterior length have now been set. The short gastric artery and vein stumps should be located posteriorly, on the left, 180° opposite the anterior fundoplication. We now insert two evenly spaced additional pledgeted U-stitches of 0-braided polyester suture, between the superior-most and inferior-most sutures, to create complete serosal apposition on the anterior fundoplication. The fundoplication itself is now completed (**Figure 47.17**). We place a right, posterior, superior gastropexy suture between the right, posterior, superior aspect of the fundoplication and the adjacent right crus, above the hiatal closure, to interpose the posterior fundoplication between the esophagus and the hiatal closure.

The final step is to perform a completion upper endoscopy to document that the fundoplication has been properly created. We document the location of the squamo-columnar

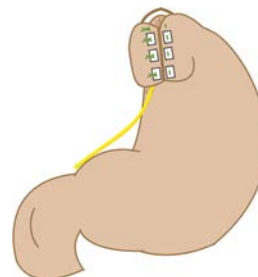


Figure 47.17 We now insert two evenly spaced additional pledgeted U-stitches of 0-braided polyester suture, between the superior-most and inferior-most sutures, to create complete serosal apposition on the anterior fundoplication. Once these two sutures are placed and tied, creation of the fundoplication is complete.

junction in relation to the fundoplication. Ideally, the squamo-columnar junction in a normal esophagus should be located at, or just above, the inferior end of the completed fundoplication. In patients with Barrett's esophagus, this point may be located *above* the fundoplication. This should be documented in the record, to avoid confusion or the diagnosis of a "slipped" fundoplication at a later date. In addition, a retroflexed view allows us to document a properly oriented fundoplication with no twisting and a good posterior valve mechanism.

The use of this technique assumes that the patient population has biometric characteristics similar to ours. Of the 250 patients we studied, we had 145 female patients and 105 male patients. The mean body mass index for females was 28.7 kg m^{-2} and for males was 28.2 kg m^{-2} . The mean age for females was 51.4 years and for males was 47.6 years (unpublished data). When our technique was first tried in

the Japanese population, the technique did not work. These authors had to recalculate the traction points for the smaller Japanese population. Once this was done, however, the authors were able to successfully reproduce our technique.⁴

An excellent video of this technique is available in the video library, Society of American Gastrointestinal and Endoscopic Surgeons Top 21 Minimally Invasive Procedures Every Practicing Surgeon Should Know, which is available from Cine-Med.

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Laparoscopic partial fundoplication

ALEX P. NAGLE AND KENRIC M. MURAYAMA

INTRODUCTION

Rudolph Nissen first described a gastric fundoplication in 1936 to protect an esophagogastric anastomosis after distal esophagectomy in a patient with a deeply penetrating esophageal ulcer.¹ He subsequently noted that the patient's heartburn symptoms improved, and surprisingly, an endoscopy performed 16 years later revealed no esophagitis. As a result, he performed his first fundoplication for gastroesophageal reflux disease (GERD) in 1955, a 360° 6 cm posterior wrap around the distal esophagus, which would thereafter be referred to as a Nissen fundoplication.² The Nissen produced excellent symptomatic control but was associated with a significant incidence of postoperative dysphagia and side effects such as inability to belch and vomit, increased flatulence, and gas bloat syndrome. This led to the development of a variety of partial fundoplications (Table 48.1). In 1961, Belsey published a series of patients undergoing a transthoracic 270° fundoplication with very good results.³ In 1962 Dor described an anterior 180° fundoplication,⁴ and in 1963 Toupet described a posterior 270° fundoplication.⁵ Modifications of the Nissen fundoplication were also developed; in 1985 Donahue published the advantages

of using a “floppy” Nissen fundoplication to help avoid the gas bloat syndrome,⁶ and in 1986 DeMeester described a Nissen fundoplication technique with only 2 cm of the fundus around the distal esophagus to help prevent gas bloat and dysphagia.⁷ However, there are groups that continue to advocate routine partial fundoplication or attempt to tailor the fundoplication based on the patient's preoperative esophageal motility.

INDICATIONS

Laparoscopic partial fundoplication is indicated in two broad clinical categories: (1) to prevent reflux following a Heller myotomy for achalasia and (2) for the primary surgical treatment of GERD. The key to success with antireflux surgery resides in proper patient selection. Although many patients find relief of their symptoms with proton pump inhibitors (PPIs), as many as 10% of medically treated patients suffer breakthrough symptoms of GERD, and up to 50% of patients require lifelong medication. Along with residual symptoms, intolerance to medication and the development of GERD-related complications represent reasons to pursue surgery. Medication failure is perhaps the most common reason patients seek surgical management. The patients most likely to benefit from surgery are those who have abnormal 24-hour pH testing scores, typical symptoms, and a good response to medical therapy.⁸

Once the patient has been deemed an appropriate candidate for antireflux surgery, a decision is made as to the type of fundoplication that will be performed. We do not specifically tailor the fundoplication based on the patient's preoperative esophageal motility, because even in patients with impaired esophageal motility, the dysmotility will typically improve after elimination of the pathologic acid reflux with a Nissen fundoplication.

Table 48.1 Types of partial fundoplication

Partial fundoplication		Description of fundoplication
Anterior	Dor	180° anterior wrap
	Belsey IV	270° anterolateral wrap (transthoracic)
	Watson	120° anterolateral wrap and esophagogastropexy
	Thal	90° anterior wrap
	Lind	270° anteroposterior wrap
Posterior	Toupet	270° posterior wrap
	Guarner	120° posterior wrap

Specific indications for a partial fundoplication as opposed to a Nissen include the following:

- Patients with preoperative dysphagia and esophageal hypomotility
- Severe aerophagia, particularly in patients with daytime reflux associated with belching
- Insufficient gastric fundus to allow a loose total fundoplication (i.e., tubular stomach or previous gastrectomy)
- Inability to tolerate the side effects of a full 360° fundoplication
- Postoperative dysphagia, despite a technically sound 360° fundoplication
- As an antireflux procedure in patients with aperistalsis of the esophagus or a named esophageal motility disorder, such as scleroderma
- Institutional preference
- As a preventive antireflux procedure in patients undergoing laparoscopic Heller myotomy for achalasia

CONTRAINDICATIONS

Antireflux surgery is contraindicated in patients who cannot tolerate general anesthesia or, in the case of the laparoscopic approach, a pneumoperitoneum. An uncorrectable coagulopathy and severe cardiopulmonary disease both preclude surgery. In patients with previous foregut surgery or in those who have had prior upper abdominal surgery, the laparoscopic approach can be attempted initially.

PREOPERATIVE EVALUATION

Preoperative evaluation is covered elsewhere in the text. Any patient considering antireflux surgery of any type should have a complete workup to understand the etiology of their disease, their anatomy, and the severity of their disease.

SURGICAL TECHNIQUE

Patient positioning and set-up

Positioning of the patient depends on the surgeon's preferred approach (i.e., from between the abducted legs of the patient or from the patient's side). Trocar placement and choice of a retractor for the left lobe of the liver are surgeon dependent.

Key fundoplication operative steps

- The gastrohepatic omentum is divided to the level of the diaphragm providing good exposure to the right crus.
- The gastroesophageal fat pad is retracted inferiorly, and the phrenoesophageal membrane is divided transversely (care taken to divide only the most anterior portion to prevent injury to the underlying esophagus and anterior vagus nerve).

- The gastroesophageal fat pad is then retracted inferiorly and to the right to expose the angle of His and the left crus. The attachments between the left crus and the fundus are divided.
- Divide the short gastric vessels and gastrosplenic ligament to fully mobilize the fundus starting at a point approximately 15 cm inferior to the angle of His near the inferior pole of the spleen.
- As the dissection continues into the mediastinum, the posterior vagus nerve is generally clearly seen and is swept along with the esophagus to the left.
- The posterior aspect of the hiatus is exposed by dividing the tissue attached to the medial border of the base of the right crus until the origin of the right crus from the left crus is visualized.
- A blunt instrument can be passed (from right to left) anterior to the crura and posterior to the stomach joining the dissection previously performed on the left side.
- Once this retrogastric window is created, a Penrose drain is placed around the gastroesophageal junction in order to provide inferior retraction on the esophagus and facilitate the remaining mediastinal dissection.
- With inferior traction on the Penrose, a full circumferential hiatal dissection is performed, thereby mobilizing the distal esophagus below the hiatus.
- The esophagus is circumferentially mobilized away from the crura, aorta, and pleura, and an accurate assessment is made as to the location of the gastroesophageal junction.
- With the esophagus in the relaxed state (i.e., no axial traction), the gastroesophageal junction should rest at least 2.5 cm below the diaphragmatic hiatus; failure to achieve this length will not allow for the fundoplication to be placed around the esophagus and will predispose to reherniation of the wrap into the chest, which can cause obstructive symptoms.
- The crura are then closed in order to repair the hernia defect.
- We do not utilize an esophageal bougie during crural closure, because the presence of an esophageal bougie stiffens the esophagus and makes it difficult to retract the esophagus anteriorly for adequate visualization of the posterior crural closure.

Toupet fundoplication (270° posterior fundoplication)

To create the Toupet fundoplication, the surgeon's left-hand instrument is passed posterior to the esophagus and grasps the most superior "floppy" aspect of the fundus along the greater curvature. The instrument is then pulled back behind the esophagus in order to wrap the fundus around the esophagus posteriorly. Once the fundus has been pulled to the right behind the esophagus, it is checked for rotational tension and torsion. To assess rotational tension, the wrapped fundus is released and observed. If it retracts back around the esophagus to the left, there is tension that

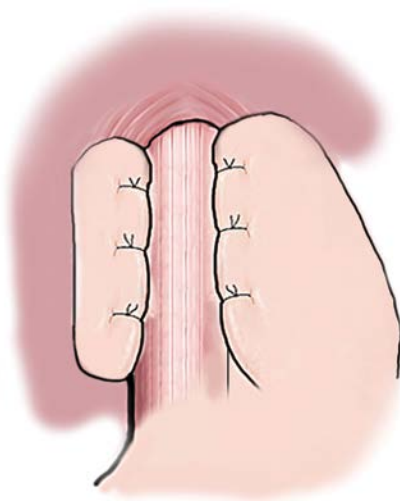


Figure 48.1 Toupet fundoplication (posterior 270°). The fundus is secured on each side of the esophagus. The initial, most proximal suture on each side also incorporates the anterior crural pillar along with the fundus and esophagus.

must be eliminated by dividing more fundic attachments. To check for a twist or entrapment of the wrapped fundus in the posterior window, the “shoe shine” maneuver is performed by sliding both sides of the fundus back and forth with both hands. It is essential that the wrap be situated entirely around the esophagus, rather than the stomach. This is because a low-lying fundoplication at the level of the gastric body can cause pooling of acidic secretions proximal to the wrap, which can then reflux into the esophagus.

Securing the Toupet fundoplication entails suturing the fundus on both sides of the esophagus (**Figure 48.1**). Identification of the anterior vagal branch helps prevent incorporation into a suture. We generally place three sutures between the right anterolateral aspect of the esophagus (at the 11 o'clock position) and the leading edge of the wrapped portion of fundus, thereby creating a wrap that is approximately 3 cm in length. Three interrupted sutures are then placed between the fundus to the left of the esophagus and the left anterior lateral wall of the esophagus (at the 1 o'clock position). The initial, most proximal suture on each side also incorporates the anterior crural pillar along with the fundus and esophagus. These sutures minimize tension on the sutures between the fundus and the esophagus. When a Toupet fundoplication is performed following a Heller myotomy, the sutures incorporate the edge of the myotomy, which also aids in holding the myotomy open.

Dor fundoplication (180° anterior fundoplication)

A Dor fundoplication is a 180° anterior fundoplication that involves folding the most “floppy” portion of the fundus

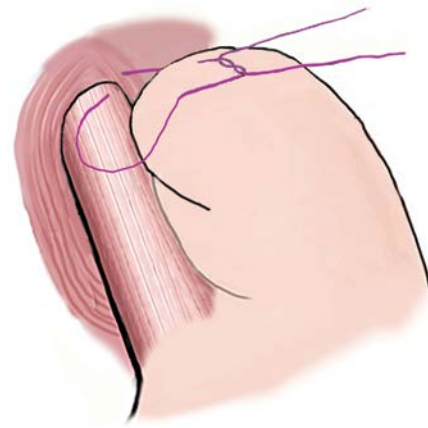


Figure 48.2 Dor fundoplication (anterior 180°). The fundus is folded across and anterior to the esophagus. The first, most proximal suture incorporates the left crura along with the fundus and the esophagus.

across and anterior to the esophagus. As with any fundoplication, it is important that the fundoplication be positioned proximally to the gastroesophageal junction. Furthermore, it is important to utilize the fundus and not the body of the stomach to create the Dor fundoplication. The Dor fundoplication is secured with two rows of sutures—one on each side of the esophagus. The inner row is performed with three to four interrupted sutures between the medial aspect of the fundus and the left side of the esophagus. The first, most proximal, suture also incorporates the left crura along with the fundus and the esophagus (**Figure 48.2**). The inner row is important to accentuating the angle of His and also stabilizing the wrap (**Figure 48.3**). The fundus is folded over the esophagus,

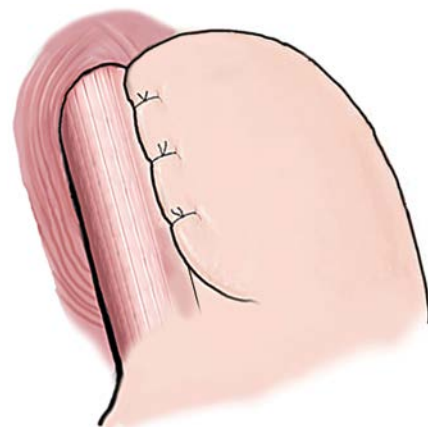


Figure 48.3 Dor fundoplication (anterior 180°). The inner row is performed with three to four interrupted sutures between the medial aspect of the fundus and the left side of the esophagus. The inner row is important to accentuating the angle of His and also stabilizing the wrap.

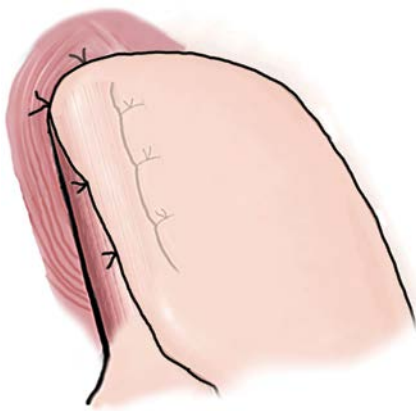


Figure 48.4 Dor fundoplication (anterior 180°). The second row of interrupted sutures is placed to fix the leading edge of the fundus to the right side of the esophagus. The first, most proximal suture incorporates the right crura along with the fundus and the esophagus. A final suture from the apex of the gastroesophageal hiatus to the fundus completes the fundoplication.

and a second row of interrupted sutures is placed to fix the leading edge of the fundus to the right side of the esophagus. Again the first, most proximal, suture should also incorporate the right crura along with the fundus and the esophagus. A final suture from the apex of the gastroesophageal hiatus to the fundus completes the fundoplication (**Figure 48.4**). When a Dor fundoplication is performed following a Heller myotomy, the sutures incorporate the edge of the myotomy.

POSTOPERATIVE CARE

Patients are started on scheduled antiemetics and intravenous ketorolac, with intravenous narcotics as needed for breakthrough pain. Unless the mediastinal dissection was difficult and required extensive esophageal and gastric manipulation, patients are allowed sips of liquids on the day of surgery and then full liquids the following morning. A routine esophagram is not obtained, unless an esophageal lengthening procedure was performed. If advancing as expected, a soft diet is initiated for lunch, and patients are discharged home in the afternoon of the first postoperative day.

Retching can occur in the early postoperative period and can cause wrap herniation above the crural repair. For this reason, any nausea should be treated aggressively with additional antiemetics, and an esophagram should be performed after any episode of vomiting to check for anatomic disruption. Any significant deviation from the normal postoperative course, such as severe nausea, significant abdominal or chest pain, fever, or tachycardia, should be assumed to be a leak from an esophageal or gastric perforation until proven otherwise. Such patients should be investigated immediately with an esophagram using water-soluble contrast, with a

low threshold for diagnostic laparoscopy if the results are inconclusive.

After hospital discharge, patients are maintained on a soft diet until their first postoperative visit at 2 weeks, and then slowly reintroduce solid foods as tolerated. Additional tests are not needed unless the patient complains of significant symptoms. Symptoms that are potentially related to either obstruction or reflux are first investigated with an esophagram to confirm the anatomy of the repair and fundoplication, and then an upper endoscopy.

OUTCOMES

The outcomes of laparoscopic partial fundoplication vary depending on the indication for surgery. In the setting of a named esophageal motility disorder, partial fundoplication has favorable outcomes in terms of controlling reflux symptoms and minimizing postoperative dysphagia. However, the use of a partial fundoplication for the primary surgical treatment of GERD remains controversial. There have been 11 randomized controlled trials and two meta-analyses comparing the differences between partial and total fundoplication.^{9–25} Many of these studies report favorable long-term relief of GERD symptoms following both anterior and posterior partial fundoplication. **Table 48.2** summarizes the longer-term outcomes of the various types of partial fundoplication. Overall partial fundoplication is associated with less dysphagia and less postfundoplication symptoms. Additionally, these studies report durable control of reflux after partial fundoplication similar to complete fundoplication. The study with the longest follow-up (18 years) includes 137 patients with chronic GERD and esophagitis randomized to either a Toupet or a Nissen fundoplication, and it showed that patients treated with a Toupet fundoplication had equivalent rates of control of symptoms of heartburn (80% versus 87%) and acid regurgitation (82% versus 90%).²⁴ Interestingly, both groups had similar rates of bloating, flatulence, and dysphagia scores, suggesting that postfundoplication symptoms after Nissen fundoplication improve with time. Despite these favorable outcomes, other groups, particularly in the United

Table 48.2 Outcomes at late follow-up (10 years or longer) following laparoscopic partial and Nissen fundoplications

Outcome following fundoplication	Nissen (%)	Toupet (%)	Dor (%)
Reflux controlled	85–90	85–90	80–85
Troublesome dysphagia	2–6	2	2
Inability to belch	35–50	30	30
Overall good or excellent outcome	90	90	90

Source: Hagedorn C et al. *J Gastrointest Surg* 2002;6:540–5; Cai W et al. *Br J Surg* 2008;95:1501–5; Watson DI et al. *Expert Rev Gastroenterol Hepatol* 2010;4(2):235–43.²⁸

States, have reported negative results with the use of partial fundoplication as a primary therapy for GERD. Jobe and colleagues in Portland, in an unselected group of 100 consecutive patients with GERD who underwent laparoscopic Toupet fundoplication, showed that more than 50% of patients had ongoing evidence of abnormal esophageal acid exposure.²⁶ They concluded that laparoscopic Toupet cannot be recommended for GERD patients with normal esophageal motility. Furthermore, the concept that the type of fundoplication should be tailored to esophageal motility is also not supported by the literature. Heider et al.²⁷ showed that, compared to partial fundoplication, most patients with dysmotility have improved esophageal peristalsis after undergoing a Nissen fundoplication. This suggests that GERD-related esophageal injury plays a role in causing dysmotility, and that abolishing pathologic reflux corrects the motility disorder. Furthermore, the incidence of dysphagia following a “short and floppy” Nissen in patients with GERD-related esophageal dysmotility is not greater than in patients undergoing partial fundoplication.

Overall, the studies comparing partial to total fundoplication are fraught with a wide variation in surgical technique, and many lack the appropriate length of follow-up. The literature does seem to support the notion that patients undergoing a partial fundoplication do experience less dysphagia, gas bloating, and flatulence; however, those patients also experience greater esophageal acid exposure, esophagitis, and need for reoperation. Further prospective randomized long-term trials are needed to help define the role of partial fundoplication for the treatment of GERD.

CONCLUSION

Laparoscopic partial fundoplication evolved as a modification to the Nissen fundoplication in an attempt to minimize postoperative dysphagia and side effects such as inability to belch, flatulence, and gas bloat syndrome, while still achieving adequate control of reflux symptoms. Both the posterior and anterior partial fundoplication, when performed by an experienced surgeon, have been reported to be highly effective with 85%–90% success rates. In our practice, patients

with preoperative dysphagia and impaired esophageal motility undergo Toupet fundoplication. We rarely if ever use an anterior fundoplication as a primary treatment for GERD. Partial fundoplications are also utilized to control GERD in the setting of aperistalsis or named motility disorders of the esophagus, such as achalasia or scleroderma. In conclusion, with appropriate patient selection and attention to technical detail, laparoscopic partial fundoplication can provide excellent results.

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Laparoscopic placement of external magnetic antireflux ring

YULIA ZAK AND OZANAN MEIRELES

INTRODUCTION

Gastroesophageal reflux disease (GERD) is a chronic disorder with a 10%–20% prevalence in the Western world,¹ prompting almost 9 million outpatient visits per year² and being responsible for over \$12 billion in yearly direct costs in the United States.³ It is characterized by the failure of the lower esophageal sphincter (LES) to prevent the flow of gastric acid and contents into the esophagus, and can lead to severe symptoms, erosive esophagitis, and malignant transformation.

The two well-established traditional methods of GERD treatment are medical acid suppression with proton pump inhibitors (PPIs) and H₂ blockers, or surgical augmentation of the LES with a partial or complete fundoplication for those who fail maximal medical management or choose to be off chronic use of acid suppression medication (discussed elsewhere). Although laparoscopic fundoplication carries an excellent safety and efficacy profile, its potential adverse effects are often deterrents affecting the patient referral patterns.⁴ These side effects include gas bloat syndrome, dysphagia, inability to belch and vomit, and reflux recurrence necessitating revisional surgery.^{5,6} As a result, the number of patients undergoing surgical treatment for GERD has declined to less than 1% of that patient population, despite an increase in laparoscopically facile foregut surgeons.^{7,8}

LINX Reflux Management System (Torax Medical, St. Paul, Minnesota) was introduced as a minimally invasive procedure aimed at the restoration of the competency of the LES without significantly altering esophagogastric anatomy. It consists of a chain of titanium beads with hermetically sealed magnetic cores that are linked together with titanium wires into a flexible ring. This expandable ring, when placed around the LES, augments the sphincter's natural resistance to opening and prevents abnormal

opening.⁷ It does not completely prevent its opening, however. When esophageal pressure rises above that of the LES and the magnetic beads combined, the sphincter can open to almost twice its collapsed diameter to allow the food bolus through. Conversely, if the intragastric pressure overcomes that of the augmented sphincter, emesis or reflux can occur. Each bead can move independently of the other beads, further adding to the plasticity of the sphincter function. As a result, the potential for gas bloat and the discomfort from the inability to belch or vomit are reduced, as compared to fundoplication.

TECHNIQUE FOR PLACEMENT

Preoperative evaluation consists of a barium swallow, esophageal manometry, and a 24-hour pH probe or Bravo capsule study. Upper endoscopy can be considered but is not mandatory. Patients with large hiatal hernias (≥ 3 cm), history of advanced esophagitis or Barrett esophagus, and those with abnormal esophageal manometry are not ideal candidates for LINX placement, and should undergo fundoplication instead. Other patient factors that may preclude device placement include allergy to titanium, stainless steel, nickel, or ferrous materials, need for future magnetic resonance imaging (MRI) surveillance, and esophageal motility disorders. Of note, the current version of the LINX implant is considered "MRI Conditional" for MRI systems up to 1.5 Tesla.

The surgical procedure is performed under general anesthesia with the patient in supine position. The laparoscopic ports are placed in a similar configuration to a fundoplication, with the exception of the right subcostal 5-mm working port that is moved more laterally to allow for better alignment of the Esophagus Sizing Tool with the gastroesophageal junction. A 12-mm working port is placed

along the left midclavicular line subcostally, a 5- or 12-mm camera port is inserted 13–15 cm inferior to the xiphoid just to the left of the midline, a 5-mm assistant port is placed subcostally along the anterior axillary line on the left, and an additional liver retractor port is positioned according to the type of the retractor used.

The pars flaccida is incised; the hepatic branch of the vagus nerve is identified coursing through it, and preserved. The lower esophageal sphincter is located in the area between this vagal branch and the inferior leaf of the phrenoesophageal ligament.⁷ The peritoneum is opened along the anterior border of the right crus just cephalad to the crural decussation, and the posterior vagus is identified. Similarly, the gastroesophageal fat pad is carefully dissected away from the gastroesophageal junction on the left, and the left phrenoesophageal ligament is exposed. A retroesophageal window is created with blunt dissection between the right vagus nerve and the posterior esophageal wall (**Figure 49.1**). Care is taken to perform the minimal dissection required to accommodate the LINX device without disrupting the existing antireflux mechanism of the phrenoesophageal ligaments. If an unexpected hiatal hernia is found during the dissection, however, it should be repaired prior to placing the LINX. A vessel loop is passed through the tunnel to aid in the manipulation of the esophagus during device positioning. The proprietary Esophagus Sizing Tool is then inserted using the right 5-mm port, and its soft tip is advanced through the retroesophageal tunnel, and curved around the esophagus at the level of the LES (**Figure 49.2**). The sizer should be positioned perpendicular to the esophagus and fit snugly but without any indentation or compression of the esophagus. The circumference is measured at least three times before selecting the LINX device of the corresponding size (from 10 to 18 beads). The implant is then inserted through the 12-mm working port, and passed through the retroesophageal window to encircle the esophagus in the same location as was measured.

The ends of the device are then connected using its three-dimensional lock mechanism, which then remains



Figure 49.1 A retroesophageal window is created with blunt dissection between the right vagus nerve and the posterior esophageal wall.



Figure 49.2 The proprietary Esophagus Sizing Tool is then inserted using the right 5-mm port, and its soft tip is advanced through the retroesophageal tunnel, and curved around the esophagus at the level of the LES.

in place, completing the procedure. This lock mechanism also allows the device to be unlocked laparoscopically, if necessary, simply by pulling the ends axially in opposite directions. Prior to this new lock mechanism, the device was secure in place using the Ti-Knot device (LSI Solutions, New York), where the ends of the device were attached to each other anteriorly with two pairs of green and white sutures (**Figure 49.3**).

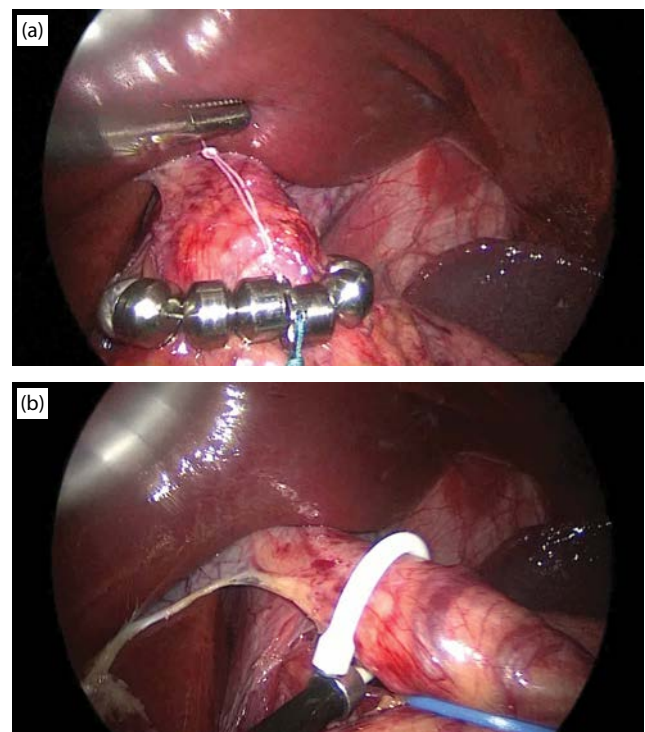


Figure 49.3 Prior to this new lock mechanism, the device was secure in place using the Ti-Knot device (LSI Solutions, New York), where the ends of the device were attached to each other anteriorly with two pairs of green and white sutures.

The patients are kept on a soft diet for 24 hours postoperatively and are then discharged on a regular diet without any acid-suppressing medications.

OUTCOMES AND CONCLUSIONS

The LINX device is technically easy to insert and easy to remove, and thus is a fairly standardized procedure that does not preclude future fundoplication. At present, its utility has been studied primarily in patients with confirmed increased acid production and gastroesophageal reflux, incomplete symptom resolution on PPIs, and without large hiatal hernias (≥ 2 –3 cm) or erosive esophagitis.

The longest-term outcomes data were published by Lipham et al. on a prospective multi-institutional case series of 44 patients after a median 3.7 years of follow-up. Eighty percent of the subjects achieved normalization of esophageal pH, with a corresponding $\geq 50\%$ improvement in the GERD Health Related Quality of Life score in all of the patients. Eighty percent of the patients were able to stop all PPI use. There was one LINX removal for severe dysphagia, one secondary to need for MRI, as well as one for persistent GERD with subsequent conversion to a fundoplication.⁹

Only one comparative study between LINX and laparoscopic Nissen fundoplication has been published to date. Sheu et al. examined 12 patients in each arm of their case-control series and found that both procedures were similarly effective in resolving GERD (75% versus 83%, respectively). While the early perioperative outcomes were similar between the groups, however, severe dysphagia requiring endoscopic dilation was more frequent after LINX placement (50%) versus Nissen fundoplication (0%).¹⁰ This rate was somewhat higher than those previously reported,^{7,11} but endoscopic dilation was very successful at relieving the dysphagia. Over time, the beads of the device become encapsulated in scar tissue, which is thought to contribute to the dysphagia with a delayed onset. Endoscopic dilation disrupts this fibrous band, alleviating the symptoms.

Several recent systematic reviews have confirmed the excellent safety profile of LINX placement.^{12,13} However, within the first 6 years of LINX implant experience in the United States, 3.4% of the devices have been removed after a median implant duration of 94 days. The most common reason for removal was dysphagia in 2.2% of the patients.¹² More serious complications leading to removal, such as erosion of the device into the esophagus, are rare. To our knowledge, there are currently six reports of LINX perforation that have been published and/or reported to the U.S.

Food and Drug Administration, Manufacturer and User Facility Device Experience. Bauer et al. published their experience with complete endoscopic removal of LINX in such a situation.¹⁴ They accomplished this by disrupting the titanium wire between the magnets with a DC Clip Cutter made for removal of the OTSC-clip (Ovesco Endoscopy AG, Tübingen, Germany), augmented with several electrical pulses, through an interventional endoscope. In their case, the LINX device was freely mobile and was able to be removed endoscopically with rat-tooth forceps once the circular chain was disrupted.

In our experience, the device is frequently covered with a layer of scar tissue external to the esophagus that prevents it from moving freely. Therefore, like most published reports, we have had to approach the removal of LINX with laparoscopy. In this method, the ring of scar tissue around the gastroesophageal junction can be sharply opened, the LINX wire transected with scissors, and the device removed through a laparoscopic port. Conversion to a conventional fundoplication can be undertaken at the same time or at a later date.

Overall, the LINX device can be placed in an efficient and safe manner and is an effective treatment for GERD with good medium-term outcomes. Future randomized studies are necessary to assess long-term outcomes and determine its efficacy relative to the current surgical gold standard, laparoscopic fundoplication.

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Laparoscopic antireflux esophageal lengthening procedure

LEENA KHAITAN AND ABEL BELLO

HISTORY OF ESOPHAGEAL LENGTHENING PROCEDURES

In 1957 J. Leigh Collis published his innovative operation for treating the difficult problem of the irreducible hiatal hernia with short esophagus, esophagitis, and stricture by providing an esophageal lengthening procedure. The concept was to create a healthy tube of stomach that was the same caliber as the esophagus that allowed the esophagus to remain in continuity with the proximal stomach but allowed for this segment to stay in the peritoneal cavity as a neoesophagus. This segment would then stay in the abdomen and prevent gastroesophageal reflux. This allowed surgeons to avoid esophagectomy or bowel interposition in patients with a shortened esophagus. The design of the operation was based on the relatively primitive understanding of the pathophysiology of the hiatal hernia and the newly emerging concept of reflux esophagitis.^{1,2} Many modifications to the original Collis were described in subsequent years to include both partial and complete fundoplication procedures.

Robert Henderson and Griffith Pearson in Toronto in 1971 combined Collis gastroplasty with the Belsey procedure in a group of difficult patients with previously failed antireflux operations and/or shortened esophagus, stricture, and transmural ulcerative esophagitis. They also used this in large combined sliding, and paraesophageal hernias that were difficult to reduce without tension, and they reported outstanding results.³⁻⁵ Mark Orringer, Henderson, and Herbert Sloan reported outcomes of combined Collis gastroplasty with the Nissen 360° antireflux gastric wrap with excellent results.⁶⁻⁸

The original Collis was again modified with the proposition of the uncut Collis-Nissen gastroplasty by creating an antireflux valve using a stapler and the addition of a fundoplication with the remaining gastric fundus.⁹⁻¹² These operations were mainly performed by a left thoracotomy. The technique underwent further modification to the most commonly performed laparoscopic approach that is used today. This is what is described in this chapter.

TECHNIQUE OF THE PROCEDURE

An early technique for laparoscopic Collis fundoplasty was described in 1996 by Swanstrom followed by a new technique using a circular and a linear stapler by Hunter in 1998.^{21,23}

Our approach to the Collis is as follows:

1. The port placement is that of a standard Nissen fundoplication.
2. The fundus of the stomach is extensively mobilized starting at the base of the fundus. Short gastrics are taken down using an ultrasonic energy device.
3. A wedge resection of the fundus is performed. First the fundus is elevated, and a reinforced staple cartridge is fired from the lateral portion of the fundus toward what will be the base of the “neoesophagus.” Then with a 54–60 F bougie in place (54F for women and 56F for men), an additional staple firing will occur toward the angle of His using the bougie as the guide.
4. The wedge of fundus excised can be removed through the port site in an EndoCatch bag.
5. The rest of the antireflux procedure is completed.

Table 50.1 Advantages and disadvantages to performing a Collis gastroplasty

Advantages	Disadvantages
Allows for a tension-free wrap and repair and adequate intra-abdominal length in patients with shortened esophagus.	Acid-producing mucosa still remains above fundoplication
Restoration of the angle of His	Continued acid exposure to the esophagus makes continuation of acid-reducing medications almost warranted
Reduces recurrence of hernia in patients with shortened esophagus	Effects of Barrett progression and esophagitis still unknown
Avoids more invasive and morbid procedures in patients with shortened esophagus such as esophagectomy and bowel interposition	Poor functionality of the distal and neoesophagus may contribute to increased postoperative symptoms such as dysphagia
Can be performed with a minimally invasive approach via the abdomen	The addition of staple lines make postoperative leaks a potential complication

Table 50.2 Evaluation and outcomes of Collis gastroplasty

	Johnson 1998	Gastal 1999	Mittal 2000	Maziak 1998	Garg 2009	Legner 2010
<i>n</i> =	9	37	10	75 gastroplasties of 94 total	85 (75% primary)	16
Study type	Retrospective	Retrospective	Retrospective	Retrospective	Retrospective	Retrospective
Inclusion criteria	<2 cm intra-abdominal esophagus	NR	<2 cm intra-abdominal esophagus (changed to <3 cm later in study)	Large hiatal hernia (sliding and paraesophageal)	<3 cm intra-abdominal esophagus	Reoperative surgery only <2 cm intra-abdominal esophagus
Approach	Laparoscopic	Open transthoracic	Laparoscopic repair, transthoracic Collis	97% open transthoracic, 3% open transabdominal	52% transthoracic, 48% laparoscopic	44% transabdominal and 56% transthoracic
Lengthening procedure	Collis	Collis	Collis over 46F bougie	Collis over 48F bougie	Collis	Collis
Antireflux procedure	Nissen	Belsey	Nissen	97% Belsey Mk IV, % Nissen	Nissen or Toupet	Nissen (81%), Toupet and Belsey
Follow-up	1 year	NR	NR	Mean 93.6 month	Median 49 month	Mean 21.9 month
Dysphagia						
Preoperative	22%	NR	NR	48%	57%	NR
Postoperative	11%	14%	NR	11%	28% (7% of total required dilatation)	NR
Heartburn						
Preoperative	44%	NR	NR	83%	76%	NR
Postoperative	11%	NR	NR	NR	24%	NR
Recurrence	NR	NR	NR	NR	NR	
Complications	None	22%	NR	2% mortality 5.3% leak	1.2% mortality, 1.2% perforation	No mortality 18.8% leak
Recommendation	Collis gastroplasty is safe	Hiatal hernia <5 cm of an esophageal stricture predicts need for gastroplasty	Short esophagus is best predicted by endoscopy; manometry and contrast studies are inaccurate	Short esophagus requires a lengthening procedure	Collis is required for inadequate intra-abdominal esophageal length	With preoperative dysphagia, Collis gastroplasty increases risk for postoperative dysphagia

Source: Adapted from SAGES Guidelines Committee, Guidelines for the management of hiatal hernia, SAGES April 2013. <http://www.sages.org/publications/guidelines/guidelines-for-the-management-of-hiatal-hernia/>.

Notes: NR, not reported.

LITERATURE REVIEW OF COLLIS

The Collis controversy

The Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) guidelines for the management of hiatal hernias indicate that there is strong evidence to suggest that a key and necessary step of hiatal hernia repair is to return the gastroesophageal junction to an infradiaphragmatic position. At the completion of the hiatal repair, the intra-abdominal esophagus should measure at least 2–3 cm in length to decrease the chance of recurrence. This length can be achieved by combinations of extensive mediastinal dissection of the esophagus and/or gastroplasty.¹³

The controversy exists around the “shortened” esophagus as a real entity.^{14,21,26–28,32} Many surgeons who perform large numbers of foregut procedures suggest that the esophagus can always be mobilized with an aggressive enough dissection to allow the 2–3 cm of intra-abdominal esophagus to sit without tension.^{14,21,26–28,32} The short esophagus is described in the literature as a gastroesophageal junction 5 cm above the hiatus or the inability to bring gastroesophageal junction back into the abdomen, resulting from long-standing reflux and subsequent inflammatory changes in the muscular wall of the esophagus with the associated healing, stricture, and contracture.^{4,14,15,16–23} A shortened esophagus is also thought to be associated with other disease processes, including type III hiatal hernias, sarcoidosis, Barrett metaplasia, caustic ingestion, scleroderma, and Crohn’s disease.^{14,24,25} Some studies have attempted to predict which patients have a short esophagus in the preoperative setting utilizing manometric and radiologic studies, but variable results have been appreciated intraoperatively,^{14,17,21,24,30,31} and hence, the controversy. It is known that more esophageal length can be achieved with a high and generous mediastinal dissection.^{29,32}

The main indication for the addition of a Collis gastroplasty has been patients with a shortened esophagus in whom adequate resting intra-abdominal esophageal length cannot be restored after extensive mediastinal dissection. One should take into consideration the previous comments. This procedure should be considered a tool that a surgeon has in his armamentarium for the management of reflux and hiatal hernia (**Table 50.1**).

The outcomes of Collis gastroplasty have been reviewed in several case series and are summarized in **Table 50.2**. One should note the paucity of data that remains regarding this procedure.

CONCLUSION

In our personal experience, we seldom have the need for an esophageal lengthening procedure during any esophageal surgery for benign disease. A generous mediastinal

dissection will almost always allow for adequate intra-abdominal esophagus and is most often accomplished transabdominally. If after extensive mediastinal mobilization and complete reduction of a hiatal hernia including excision of the hernia sac, the esophagus does not sit in the peritoneal cavity, there is enough evidence to show that an esophageal lengthening procedure can be performed safely.^{13,16,15,33,34} The clinical outcomes of this intervention are poorly studied because this procedure is increasingly rarely performed. However, it is a nice option for the surgeon to keep in the toolbox if needed.

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Laparoscopic repair of paraesophageal hernia

C. DANIEL SMITH

BACKGROUND

Hiatal hernia nomenclature

Before discussing the workup and management of paraesophageal hernia, it is first necessary to be clear about nomenclature and taxonomy of hernias at the esophageal hiatus. The term *paraesophageal hernia* is used interchangeably with hiatal hernia to indicate the anatomic abnormality of herniation of abdominal content, typically part or all of the stomach, through the esophageal hiatus and into the mediastinum. Technically speaking, a paraesophageal hernia, also known as a type II hiatal hernia, is a subtype of hiatal hernia. The other two subtypes include type I, sliding-type hernia, and type III, a combination of type I and type II hernias ([Figure 51.1](#)). In this chapter, I consider all types of hiatal hernias.

Hiatal hernia anatomy

The distinction becomes important when considering anatomy and clinical consequences of the different types of hiatal hernia. The best way to think of the differences relates to the phrenoesophageal ligament (PEL). In type I, sliding-type hiatal hernia, the PEL is intact, but lax. This allows the gastroesophageal junction (GEJ) to migrate above its normal relationship with the esophageal hiatus and into the mediastinum ([Figure 51.2](#)). Typically, it is only the gastric cardia that herniates in type I hernias. In a type II, paraesophageal hernia, there is a defect in the PEL rather than laxity. With this, the GEJ remains fixed by the PEL at the esophageal hiatus, while a defect in the PEL allows herniation through the esophageal hiatus ([Figure 51.3](#)). If the hiatal and PEL defect is large enough, the fundus and body of the stomach herniate alongside the fixed GEJ creating a torsion or volvulus of the stomach. Finally, the type III

hiatal hernia is both laxity and a defect in the PEL resulting in the GEJ, fundus, and/or body of the stomach to herniate into the chest ([Figure 51.4](#)).

Hiatal hernias significance

Hiatal hernia is an extremely common condition. Over 60% of patients over the age of 60 will have endoscopic or radiographic evidence of a hiatal hernia. The vast majority of these are type I, sliding-type, hiatal hernias and are of little clinical consequence. Only 10% of hiatal hernias are either type II or type III, which may require surgical repair based on the anatomic deformity alone. Typically, the patient with a type II or type III hiatal hernia is experiencing mechanical problems related to having a significant portion of their stomach herniated into the chest. This can include chest pain, dysphagia, regurgitation, and difficulty breathing. Patients with a true type II, paraesophageal hernia often have few chronic symptoms, but rather, have experienced an episode of acute-onset severe chest pain, often during or shortly after a meal, that abates only after vomiting or a visit to an emergency room where a nasogastric tube relieves the pain. This represents an episode of gastric volvulus, and it is the risk of gastric torsion or volvulus progressing to incarceration and strangulation that represents the most significant clinical problem with type II hiatal hernia. This is a rare occurrence, but it is often the most compelling reason to recommend elective surgical repair.

DIAGNOSIS

Most hiatal hernias are found incidentally during imaging or endoscopy for other reasons. If asymptomatic, most primary care providers recommend observation only. While this is perfectly appropriate for type I hiatal

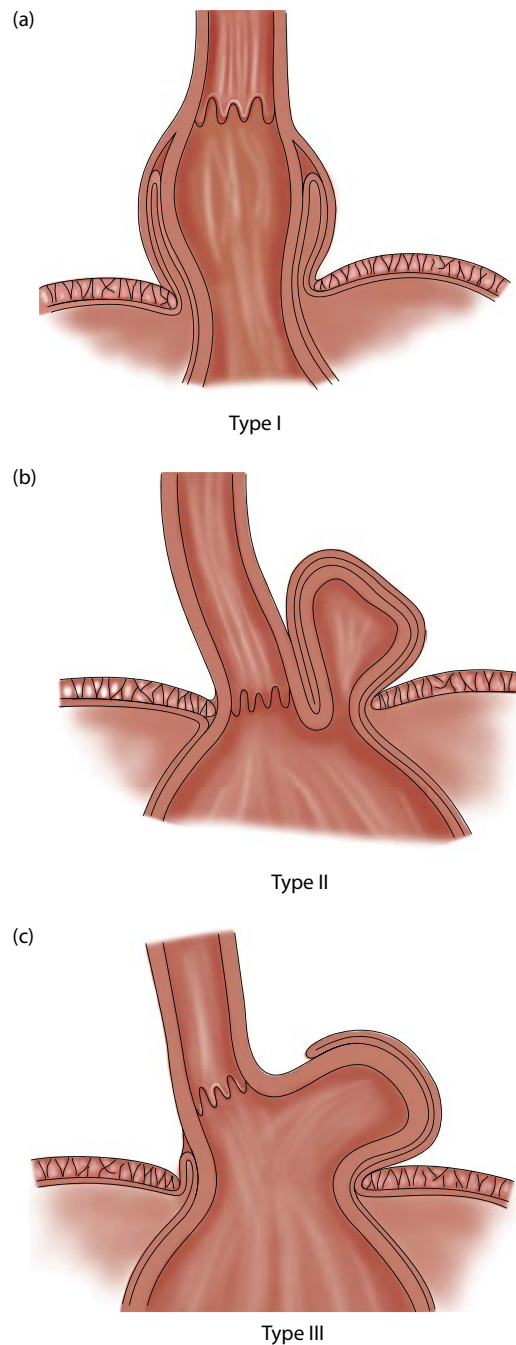


Figure 51.1 Hiatal hernia classifications.

hernia, asymptomatic type II and type III hernias should be referred for surgical opinion. All type II hiatal hernias, and many type III hernias, should be considered for repair even if asymptomatic. This is due to the high likelihood that these large hernias will eventually become symptomatic and clinically significant, and elective repair before becoming giant hiatal hernias (entire stomach herniated into chest) or presenting emergently for incarceration will result in better overall outcomes from surgery.

Generally speaking, the surgical workup of a hiatal hernia should include imaging to define the type and extent of



Figure 51.2 Contrast swallow depicting a type I hiatal hernia.

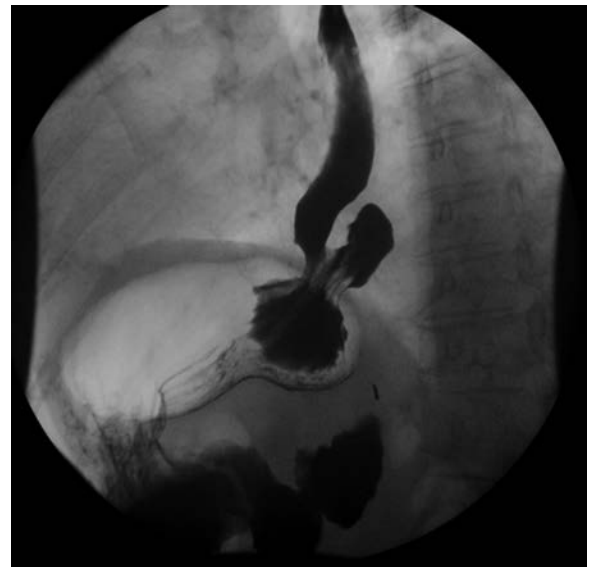


Figure 51.3 Contrast swallow depicting a type II hiatal hernia.

the hernia, and testing to determine surgical risks. Barium swallow is the most helpful imaging study to determine the type and size of hernia. Esophagogastroduodenoscopy (EGD) is confirmatory and identifies any associated pathology, such as esophagitis or gastritis. EGD is particularly helpful in identifying linear ulcers or erosions of the gastric cardia (Cameron erosions) that may accompany a large hiatal hernia and explain the chronic anemia seen in



Figure 51.4 Contrast swallow depicting a type III hiatal hernia.

these patients. In patients with symptoms clearly attributable to a hiatal hernia (e.g., dysphagia, chest pain, and regurgitation), a contrast swallow and EGD are all that is needed to recommend surgical repair. Esophageal motility is often considered since a fundoplication is recommended as part of the surgical repair (see section Surgical Technique), but the anatomic loss of the LES-esophageal hiatus relationship, and the other anatomic changes of the esophagus with large hiatal hernias can make esophageal motility difficult to interpret, and are often not helpful.

MANAGEMENT

Type I hiatal hernia (sliding hiatal hernia)

Asymptomatic type I hiatal hernia typically requires no further management. The most common clinical scenario associated with a type I hiatal hernia is gastroesophageal reflux disease (GERD). In that situation, the management of patients with a type I hiatal hernia should follow the workup and management of GERD. Put simply, the hiatal hernia is incidental to and secondary to the workup and management of GERD.

Type II hiatal hernia (paraesophageal hernia)

All type II, paraesophageal, hiatal hernias should be surgically repaired. While the chance of incarceration or strangulation is rare (less than 5%), the occurrence of strangulation or incarceration is often fatal, making elective repair the

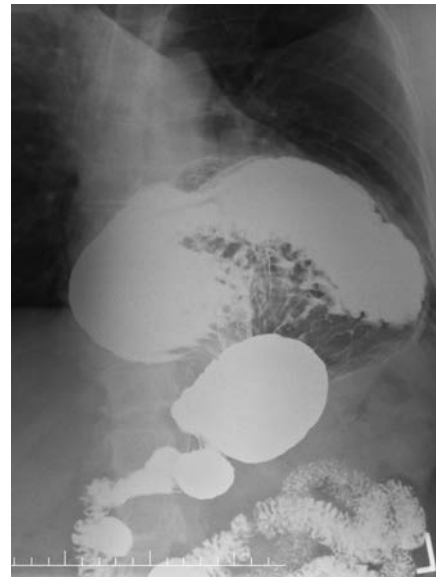


Figure 51.5 Contrast swallow depicting a giant hiatal hernia with organoaxial volvulus.

preferred way to manage these hernias. Also, when managed emergently, a satisfactory long-term outcome of surgical repair often requires multiple procedures, since the initial operation is usually a salvage procedure only.

Type III hiatal hernia (combined hiatal hernia)

Management of a type III hiatal hernia depends on size, symptoms, and the patient's age. In general, if one-third or more of the stomach is herniated into the chest, repair should be considered even if asymptomatic, especially in younger patients (age 60 or less). Over time, most type III hiatal hernias enlarge and become symptomatic, and in younger patients, rather than waiting for the hernia to enlarge and become more difficult to manage surgically, it is better to intervene early. As evidence in support of this strategy, elderly patients are more likely to present with the majority of their stomach herniated into their chest and usually have known about a hiatal hernia for decades; the outcome of surgical repair of these giant hiatal hernias ([Figure 51.5](#)) is worse than in smaller hernias repaired in younger patients. An exception to this would be an older patient or a patient with significant medical comorbidity, making it unlikely that the patient would survive long enough to have the hernia progress anatomically. Repair should be offered for all symptomatic type III hiatal hernias unless surgery is contraindicated due to comorbidity.

SURGICAL TECHNIQUE

The principles of surgical repair include (1) reducing the herniated content back into the abdominal cavity, (2) mobilizing

the hernia sac out of the mediastinum and resecting the sac, (3) establishing adequate esophageal length, (4) reconstructing the esophageal hiatus, and (5) performing esophago-gastric fundoplication to help maintain the GEJ below the esophageal hiatus and prevent potential future GERD.

A laparoscopic repair is the technique of choice. Some have suggested that the recurrence after laparoscopic repair may exceed that of an open repair, but this has not been borne out in long-term outcome studies. More importantly, the perioperative morbidity is extremely favorable when compared to an open approach, leaving the open technique only appropriate for those most advanced hiatal hernias, typically redos, especially when mesh was used in the initial repair, or intrathoracic incarceration.

Surgical technique specifics

Using a standardized technique, very favorable outcomes can be achieved. The following technique adheres to the principles of repair outlined above.

The patient is positioned supine with the legs either split or in stirrups so that the surgeon can stand between the patient's legs to operate (**Figure 51.6**). An assistant stands on the patient's left, and video monitors are positioned over the patient's head and right shoulder. A five-trocar technique is used. Stepwise, the operation follows the following sequence:

1. Pull easily reducible herniated stomach bag into abdomen
2. Divide short gastric vessels to expose base of left crus
3. Enter mediastinum at base of left crus dividing the hernia sac at this location to expose anterior surface of aorta
4. Mobilize hernia sac from left posterior hiatus following the undersurface of the left crus up to the crural arch on the left as the sac is pulled out of the mediastinum
5. Extend this posterior mobilization of the sac to the right behind the hiatal content and over the crural arch, all from the left, and in this way reduce the stomach out of the mediastinum along with the sac
6. Move to the right side of the hiatus and connect the posterior dissection from the base of the right crus
7. Encircle the hiatal content with a Penrose drain above the mobilized hernia sac, and with this additional retraction, complete the hiatal dissection well up into the mediastinum
8. Mobilize the esophagus out of the mediastinum until the GEJ rests 2–3 cm below the esophageal hiatus
9. Perform intraoperative EGD to identify squamocolumnar junction and assure the GEJ is well below the hiatus
10. Resect the hernia sac taking care to not undercut the right and left vagus nerves
11. Reconstruct the esophageal hiatus with permanent sutures placed initially posteriorly, and then anteriorly until the crura efface the nonretracted esophagus
12. Perform a 360° fundoplication calibrated around a 56 Fr dilator across the GEJ
13. Selectively place a gastrostomy tube for stomach venting and decompression in cases where extensive gastric manipulation will likely lead to delayed return of normal gastric function

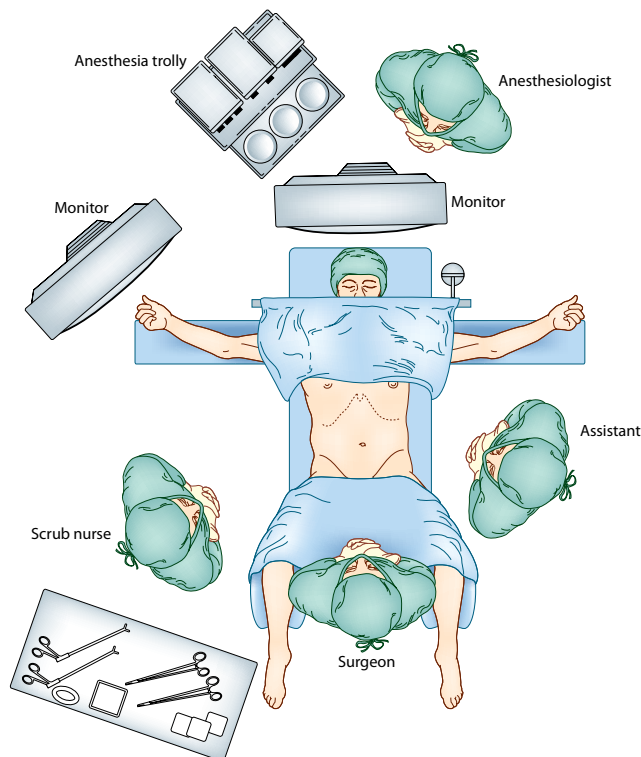


Figure 51.6 Operating room setup for laparoscopic hiatal hernia repair.

COMPLICATIONS AND POSTOPERATIVE CARE

Complications after laparoscopic hiatal hernia repair occur in less than 5% of patients and usually involve pulmonary issues (pneumothorax created due to pleural breach during mobilization of the hernia sac out of the mediastinum and atelectasis) or nausea requiring antiemetics and truncated diet progression. Both of these problems are managed with support (oxygen and pulmonary toilet) and expectantly. The main focus of postoperative care relates to diet restriction during the first month postoperatively when edema may lead to food impaction if patients progress to a regular diet too quickly, and limits on physical activity to allow sufficient healing before straining the hiatal repair. Patients are placed on a liquid and then soft food diet for at least 1 month postoperatively, and are restricted for a full month from lifting any more than 10 pounds or doing anything more vigorous than walking.

Typically patients can be discharged on the first postoperative day. Any difficulty tolerating liquids while in the hospital should prolong hospital stay so that intravenous fluids can be maintained. The dehydrated patient is more

likely to experience nausea and retching. Any retching postoperatively that leads to worsening dysphagia prompts performance of a contrast swallow. Rarely, immediate postoperative retching (within 1–3 days) can result in herniation of the fundoplication into the chest. If this occurs and is identified within 1–4 days, the patient can be immediately returned to the operating room to reduce the hernia and reconstruct the hiatus. If this occurs and is not found within a few days postoperatively, it is necessary to then wait 6–12 weeks before attempting to fix the hernia, since the early postoperative inflammation and scarring often lead to injury to the stomach or esophagus if repair is attempted before this time has elapsed.

OUTCOMES

Outcomes of hiatal hernia repair have focused on symptom control and recurrence. In several studies documenting long-term outcomes, over 90% of patients have good resolution or control of symptoms and are very satisfied with their outcomes. Recurrence has been the subject of significant study and debate. Many series published in the literature document an anatomic failure or recurrence of the hernia in 30%–50% of cases. While this sounds like an utter failure, it is important to differentiate anatomic failure from clinical failure. In many different reports, while the anatomic failure is defined as transdiaphragm migration of a fundoplication or the GEJ, the clinical outcomes remain durable and excellent with nearly 90% of patients remaining symptom free and very satisfied with their outcome.

To make sense of these apparently conflicting outcomes, it is helpful to again reflect on the different types of hiatal hernia, and remember that type I, sliding-type hiatal hernia is rarely of clinical significance unless associated with pathologic GERD. Most recurrent hiatal hernias are type I hiatal hernias and are of no clinical significance. Additionally, a hiatal hernia recurrence that is a type II or type III hernia is extremely rare and does not have the potential for volvulus, incarceration, and strangulation of a primary type II or III hiatal hernia due to the scarring that limits free herniation and rotation/torsion. This is why using anatomic recurrence as the measure of success or failure of surgical intervention leads to an overly aggressive surgical intervention (see the discussion in the next section on the use of mesh to reconstruct the esophageal hiatus). That said, the high anatomic recurrence has troubled surgeons, and there has been great interest in decreasing this anatomic failure rate, especially through the use of mesh.

SHOULD MESH BE USED TO REPAIR ALL HIATAL HERNIAS?

The high rate of anatomic failure of hiatal hernia repairs has led many to suggest that some sort of prosthetic should be used to reduce these failures. Many argue that the

principle of “tension-free” repair embraced for abdominal wall hernias can be applied to hiatal hernias as well. Over the past several years, many types of prosthetic material have been used for reinforcement of the crural repair, or hiatal reconstruction when the crura cannot be approximated. A nonrandomized prospective study suggested a lower recurrence rate without any increase in dysphagia in a series of patients where permanent mesh (polypropylene) was used in all patients undergoing laparoscopic Nissen fundoplication. A more recent collection of experiences from several experienced foregut surgeons identified over 20 patients in whom mesh was used to reconstruct the esophageal hiatus where mesh eventually eroded into the esophagus, leading to significant complications including progression to esophagectomy in several patients. Several single institution case series have confirmed the hazards of using prosthetic (permanent) mesh for reinforcement of reconstruction of the esophageal hiatus. Biomesh has been advocated as an alternative to permanent mesh. In the only prospective randomized study comparing repair with a biomesh (reabsorbed) versus no mesh, a significant reduction in hernia recurrence was found in the biomesh group at 6 months after surgery, suggesting a benefit to mesh without the associated risk of long-term mesh erosions or complications. Longer-term follow-up of this study confirmed no long-term benefit of the biomesh, with recurrences equally present regardless of whether mesh was used in the primary repair.

Today there is no evidence that mesh use decreases anatomic recurrence unless permanent mesh is used, and with permanent mesh, while anatomic recurrence might be decreased, the risk of mesh-related complications, especially the potential for erosion and eventual esophagogastric resection make the routine use of mesh difficult to support. This is especially true when considering that most anatomic recurrences are of little clinical consequence, and a redo hiatal hernia repair carries risk comparable to a first-time hiatal hernia repair.

Finally, there will be occasions where it is impossible to effect a tissue reconstruction of the esophageal hiatus without some adjunct maneuver. Today, the most common maneuver to effect a primary soft tissue reconstruction in the face of a massive hiatal hernia is to create a relaxing incision in the diaphragm parallel to the inferior vena cava and the right hemidiaphragm (Figure 51.7). A similar incision can be made in the left hemidiaphragm, if necessary. With this, the right and left crura of the diaphragm can usually be approximated behind the esophagus to affect a tissue repair. The remaining diaphragmatic defect(s) can then be patched using a prosthetic mesh. The advantage of this approach is isolating the mesh from the esophageal hiatus and avoiding the esophageal/mesh interaction that can result in erosion and need for resection.

In summary, hiatal hernia is very common. Type I hernias rarely requires surgical management unless it is associated with GERD requiring operative management. Type II hernias, while rare, should be repaired to prevent volvulus

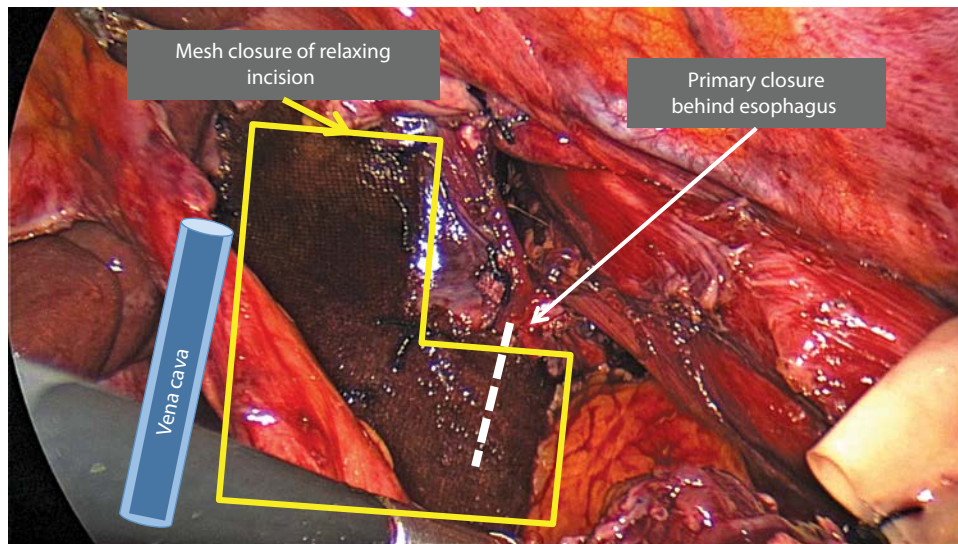


Figure 51.7 Intraoperative photo detailing placement of mesh to repair a relaxing incision during primary tissue reconstruction of the esophageal hiatus.

and potential for strangulation. Type III hernias should be repaired when symptomatic, or when found in a younger patient where enlargement is inevitable and early repair should be most successful. The laparoscopic approach is today's standard of care. Clinical outcome is excellent even if anatomic recurrence is high, since most anatomic recurrence is of a type I hernia. Routine use of mesh has virtually no positive impact on outcomes. If mesh is needed, it should be placed away from the esophageal hiatus to repair an iatrogenic defect created to facilitate a primary tissue reconstruction of the hiatus.

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Reoperative surgery after fundoplication

CARMEN L. MUELLER, LORENZO E. FERRI, AND GERALD M. FRIED

INTRODUCTION

Reoperative surgery after previous fundoplication is complex. Before proceeding, the surgeon must carefully consider the indications for reoperation and perform the investigations necessary to sufficiently understand the cause of the patient's symptoms and possible operative solutions. Knowledge of what was done at the previous operation is crucial to reoperative planning and assessment of operative risks. Careful dissection technique, use of on-table endoscopy, and an approach to intraoperative complications help optimize the likelihood of safe and successful reoperative hiatal surgery.

INDICATIONS FOR REOPERATION

There are many reasons a patient may present for consideration of reoperation after previous fundoplication surgery. The majority of these can be divided into two groups: patients who present with dysphagia, and patients who complain of reflux symptoms ([Table 52.1](#)). In North America, total reoperation rates after fundoplication have been reported to be 7% at 10 years, with the highest rate occurring within the first year after initial operation (1.7% per year).¹ While as many as 50% of patients after paraesophageal hernia repair have been shown to develop recurrences at long-term follow-up, the majority of recurrences are small and asymptomatic. Patients with anatomic recurrence, but without significant symptoms, generally do not require revision and can be followed.²

Causes of dysphagia after fundoplication are usually anatomical. Recurrent hiatal hernia with obstruction, wrap displacement, tight wrap, narrowing of the hiatal orifice, or erosion of hiatal mesh into the esophagus, are all possible causes of postoperative dysphagia. If patients are routinely

evaluated preoperatively with esophageal manometry, a missed esophageal motility disorder as a cause of postfundoplication dysphagia should be rare; however, secondary achalasia after fundoplication is a well-described, albeit rare, complication.³

Causes of reflux after fundoplication can be anatomical or functional, and careful investigations must be done to determine the specific reason in each case. Potential reasons for recurrent reflux after fundoplication include too loose a wrap, wrap disruption, recurrent hiatal hernia, and new onset or progression of obesity.

PREOPERATIVE EVALUATION AND PLANNING

Careful evaluation with history, endoscopy, and imaging is essential for all patients in whom reoperative hiatal surgery is considered. Before offering a second operation, it is crucial to achieve a clear understanding of each patient's unique situation and indication(s) for surgery.

History

For patients with dysphagia, a detailed history of the timeline and severity of symptoms should be taken, as well as the appropriate imaging studies done, in order to determine the true cause of symptoms. In the early postoperative period, particularly after total 360° fundoplication, a short period of dysphagia is not unusual and typically resolves after several weeks. However, a patient presenting with severe, delayed, and/or persistent symptoms should be investigated.

A similar approach should be taken with recurrent reflux, and a focused history regarding the onset of symptoms, provoking factors, dietary and lifestyle habits, and significant weight changes should be documented.

Table 52.1 Possible indications for reoperative fundoplication by primary presenting symptom

Dysphagia	Reflux/Regurgitation
Displaced wrap	Loose wrap
Tight wrap	Wrap disruption
Recurrent hiatal hernia	Significant weight gain/obesity
Mesh erosion	Recurrent hiatal hernia
Esophageal dysmotility	
Hiatal narrowing	

Investigations

UPPER GASTROINTESTINAL SERIES

This dynamic study can provide considerable information regarding esophagogastric anatomy and function. Detectable abnormalities include esophageal dilatation, narrowing or obstruction of the gastroesophageal (GE) junction, GE reflux, hiatal hernia, delayed gastric emptying, wrap disruption or misplacement, and fistulas (**Figure 52.1**).

UPPER ENDOSCOPY

Evaluation with upper endoscopy can be very useful in determining postsurgical anatomy and documenting objective evidence of acid reflux. Esophageal length, location of the squamocolumnar junction in relationship to the

diaphragmatic hiatus, location and quality of the previous fundoplication, size of the GE junction aperture, presence of fundus above the wrap, twisting of mucosal folds, signs of mesh erosion, presence and size of hiatal hernia, esophagitis, Barrett changes, bile reflux, and signs of gastroparesis can all be detected with the gastroscope (**Figure 52.2**).

24-HOUR PH

Recurrent symptoms of heartburn should be evaluated for objective evidence of reflux with 24-hour pH testing unless there is evidence on endoscopy. There is ample evidence that the majority of patients with heartburn after fundoplication in fact have no demonstrable acid reflux with objective testing.⁴ In the absence of a clear anatomical cause of recurrent reflux after fundoplication (such as complete wrap disruption), this study should be repeated in all patients presenting with reflux complaints. Repetition of the test provides objective evidence of the degree of acid reflux and allows comparison to preoperative results.

COMPUTED TOMOGRAPHY

Computed tomography, ideally with oral and intravenous contrast, is largely used to assess patients in the acute setting. This static study is most useful to identify gross anatomical abnormalities, such as recurrent large hiatal hernias with gastric volvulus and obstruction (**Figure 52.3**).

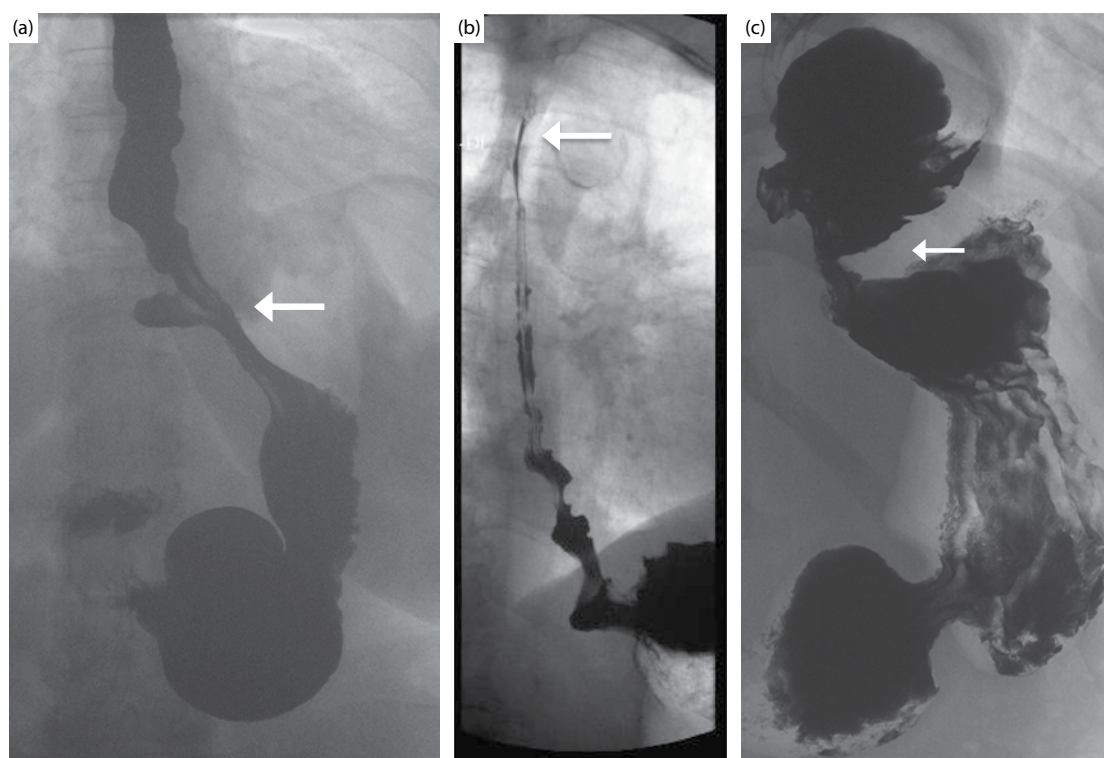


Figure 52.1 Sample upper gastrointestinal images after fundoplication. (a) Normal upper gastrointestinal examination following Nissen fundoplication (arrow: contrast enhancing part of 360° wrap). (b) Reclined image post-Dor fundoplication showing reflux of contrast to the cervical esophagus (arrow). (c) Slipped wrap with arrow indicating fundoplication location at gastric body.

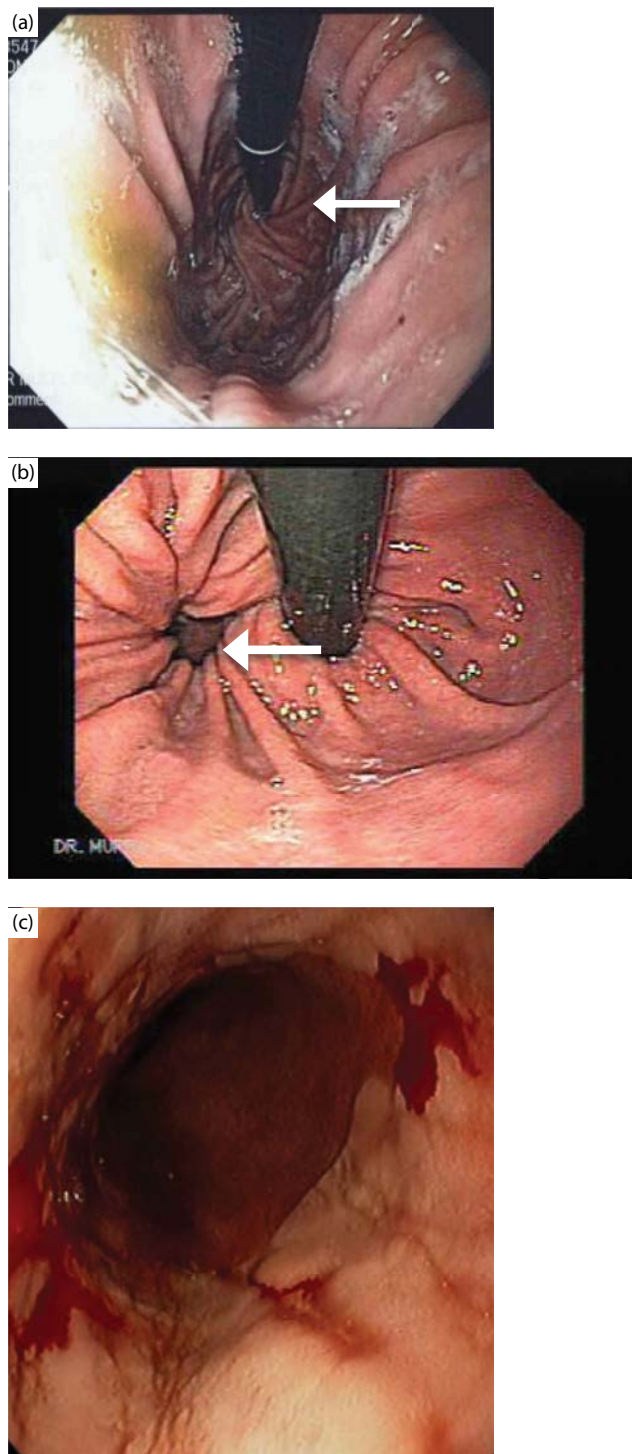


Figure 52.2 Endoscopic images after fundoplication. (a) Normal retroflexed view showing 360° wrap (arrow). (b) Recurrent small-neck hiatal hernia (arrow) with wrap disruption. (c) Severe recurrent reflux causing erosive esophagitis.

ESOPHAGEAL MANOMETRY

Manometry can be useful to evaluate patients with persistent dysphagia in whom no anatomical explanation can be found. This study may be particularly informative in

patients who have remotely or never undergone manometry in the past. Additionally, it may identify the rare patient with fundoplication-induced achalasia.³

RISKS AND CONSIDERATIONS OF REOPERATIVE FUNDOPLICATION

Risks

Reoperative surgery is never easy, particularly so at the esophagogastric junction. Thus, the decision to reoperate should never be taken lightly; the risk of major complications is not insignificant. Adhesions from prior surgery can make dissection difficult and risk causing injury to vital surrounding structures, including the esophagus, stomach, liver, inferior vena cava, and aorta. The rate of significant intraoperative complications with reoperative hiatal surgery depends on previous surgical technique (e.g., use of mesh, see the next section), patient factors, and acute versus elective presentation. Compared to primary surgery, revisional fundoplication is associated with longer operative times and a higher rate of conversion to open surgery than primary laparoscopic procedures.^{5,6} Pneumothorax, vagal injury, leaks related to Collis gastroplasty, and bleeding are some of the commonly reported complications of reoperative hiatal surgery.^{7,8} Esophageal and/or gastric perforation requiring repair, ranging from primary closure to esophagectomy, have been reported in many cases, particularly where synthetic mesh was previously used for hiatal reinforcement.⁹

Considerations

PREVIOUS SURGICAL APPROACH

Currently, laparoscopic fundoplication has supplanted thoracic and open approaches as the most common operative approach for primary antireflux surgery. However, prior open abdominal or thoracic surgery frequently results in significantly greater adhesions than if the fundoplication was performed laparoscopically. While a previous open approach does not necessarily preclude an attempt at laparoscopic reoperation, conversion to laparotomy should be considered early if the procedure cannot proceed safely.

A previous thoracic approach does not preclude an attempt at transabdominal reoperation, either open or laparoscopic. However, the surgeon should be prepared to perform a thoracotomy if dense adhesions are encountered in the chest that cannot be safely dealt with from the abdomen. This is particularly so if the prior repair was a transthoracic Belsey repair, as the adhesions and sutures are extremely difficult to manage from the abdomen.

CHOICE OF FUNDOPLICATION/PROCEDURE ON REOPERATION

Multiple options exist for redo fundoplication after failed primary operation, and selection depends on initial presentation as well as indications for reoperation ([Figure 52.4](#)).

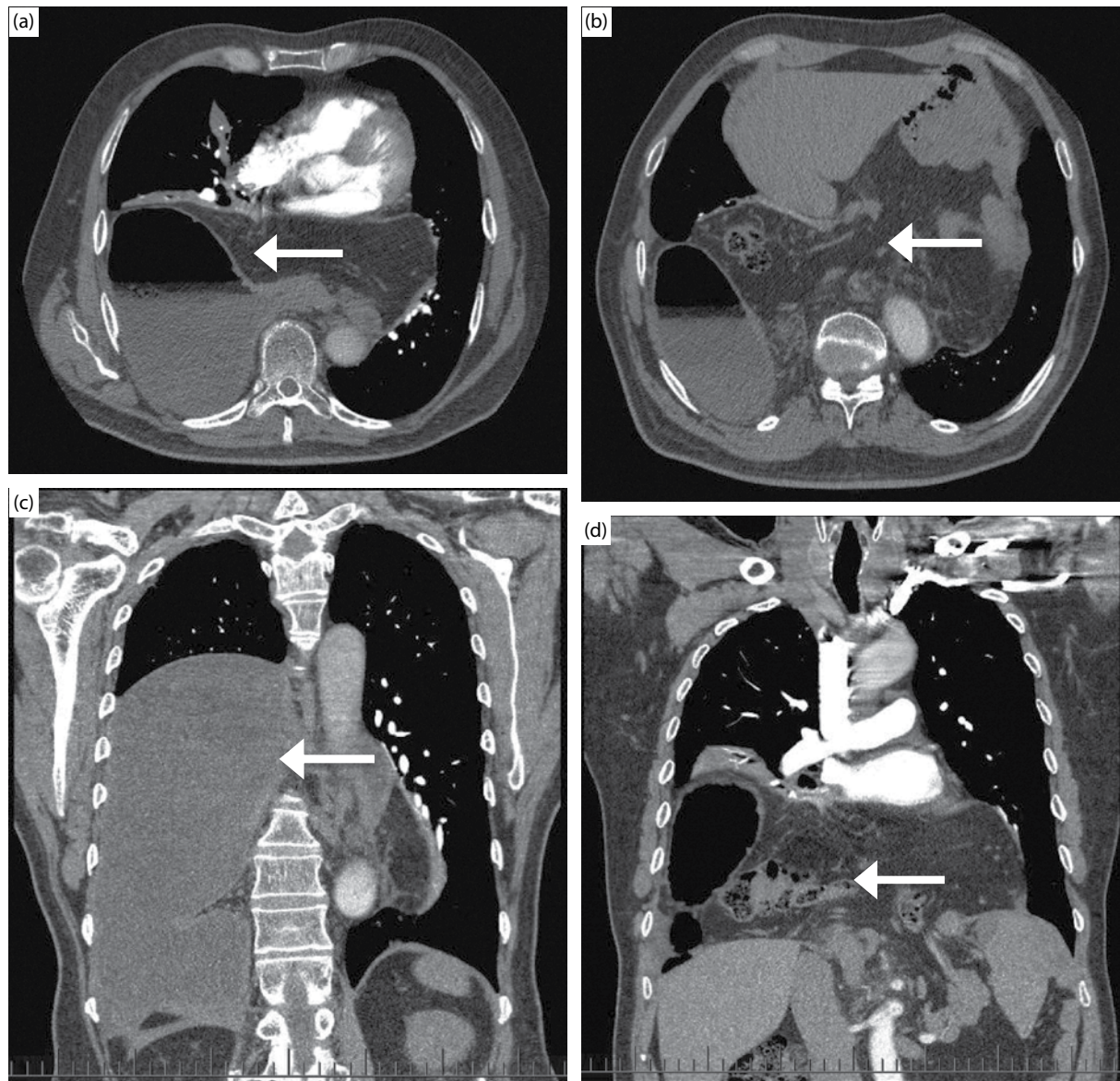


Figure 52.3 Chest computed tomography images of acute paraesophageal hernia recurrence with gastric volvulus and obstruction. This patient presented with shortness of breath and dysphagia following an episode of vomiting 2 weeks after paraesophageal hernia repair with Nissen fundoplication. Axial images demonstrating (a) intrathoracic stomach with air fluid level and (b) tight diaphragmatic defect (arrows). Coronal images showing (c) dilated and fluid-filled obstructed stomach and (d) intrathoracic transverse colon (arrows).

Dysphagia

The most common causes of dysphagia postfundoplication are misplaced/slipped wrap and wrap herniation into the chest. Choice of fundoplication at reoperation depends on the initial indication for surgery (reflux alone or paraesophageal hernia) and degree of reflux at reoperation. For patients who previously underwent primary antireflux surgery who present with shifted anatomy, redo Nissen or Toupet fundoplication is currently recommended.¹⁰ For those who primarily underwent paraesophageal hernia repair with no history of significant reflux symptoms, Dor fundoplication may be preferable, as it has a low rate of dysphagia compared to Nissen

fundoplication and provides a secure fundal-crural pexy, while providing acceptable long-term reflux control.^{11,12}

Reflux

For patients presenting with loose or disrupted wraps and significant recurrent reflux symptoms, redo Nissen or Toupet fundoplication is the procedure of choice.¹⁰

Morbid Obesity and Recurrent Reflux

Concern that obesity is a risk factor for recurrent reflux after fundoplication and the observed success of Roux-en-Y gastric bypass for the treatment of obesity have led to the recent

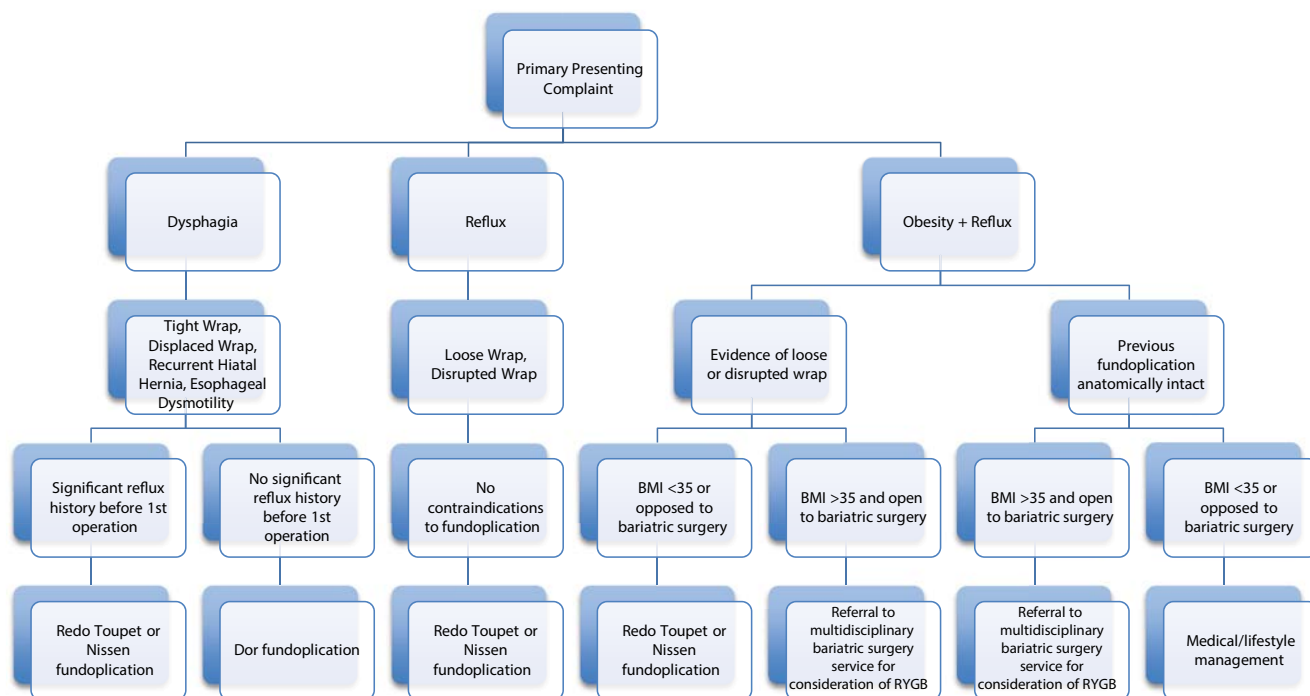


Figure 52.4 Choice of fundoplication/procedure in reoperative hiatal surgery. (RYGB, Roux-en-Y gastric bypass.)

paradigm shift in antireflux surgery, with this procedure supplanting fundoplication as the preferred operation for morbidly obese patients (body mass index [BMI] > 35) with reflux. In general, sleeve gastrectomy should be avoided in obese patients with recurrent paraesophageal hernia, as this procedure is known to increase reflux symptoms.^{10,13} Morbidly obese patients who failed primary antireflux operation and express interest in bariatric surgery should be evaluated by a multidisciplinary bariatric surgery team to determine surgical candidacy. Those who are not bariatric surgery candidates or refuse bariatric surgery may still experience reflux relief with reoperation for failed antireflux surgery.¹⁴

HIATAL MESH

The popularity of mesh reinforcement of the crural closure has waxed and waned over time. Recently, strong evidence has emerged that mesh reinforcement, either synthetic or biologic, does not significantly reduce hiatal hernia recurrence rates versus primary suture repair over long-term follow-up. Moreover, the majority of patients with recurrences after suture repair and biologic mesh installation are asymptomatic.^{2,15,16} In contrast, considerable complications have been reported from the use of synthetic mesh at the hiatus, including dysphagia, erosion into the stomach or esophagus, esophageal perforation, and the need for partial gastrectomy or esophagectomy on reoperation.^{9,17} When undertaking reoperative hiatal surgery, knowledge of previous mesh use is imperative to operative planning, risk assessment, and informed consent discussions, as the repair is frequently much more difficult than without prior prosthetic use.

INTRAOPERATIVE TECHNICAL CONSIDERATIONS

Use of intraoperative endoscopy

Intraoperative endoscopy is extremely valuable in reoperative hiatal surgery for a variety of reasons. It can be used for transillumination to facilitate exposure of the esophagus, may facilitate the identification of esophageal or gastric injuries as a result of dissection, can help the surgeon determine the adequacy of dissection, and can be used to accurately identify the location of the squamocolumnar junction. Furthermore, easy passage of the endoscope post-fundoplication is reassuring that the wrap is not too tight, and the scope can be used to confirm the wrap is properly positioned before leaving the operating room. This technique is relied upon heavily in our institution for the successful completion of complex hiatal cases.

Dissection technique and extent

In reoperative hiatal surgery, the normal dissection planes may be obscured by dense adhesions, and structures may not be easily identifiable initially. The inferior vena cava may be closer to the operative field than expected due to traction from previous scar tissue, and the esophagus and stomach are also at risk of iatrogenic perforation. Careful sharp dissection without energy is often the safest approach until the anatomy becomes clear. If hiatal adhesions are dense and the anatomy is poorly defined, the esophagus can be

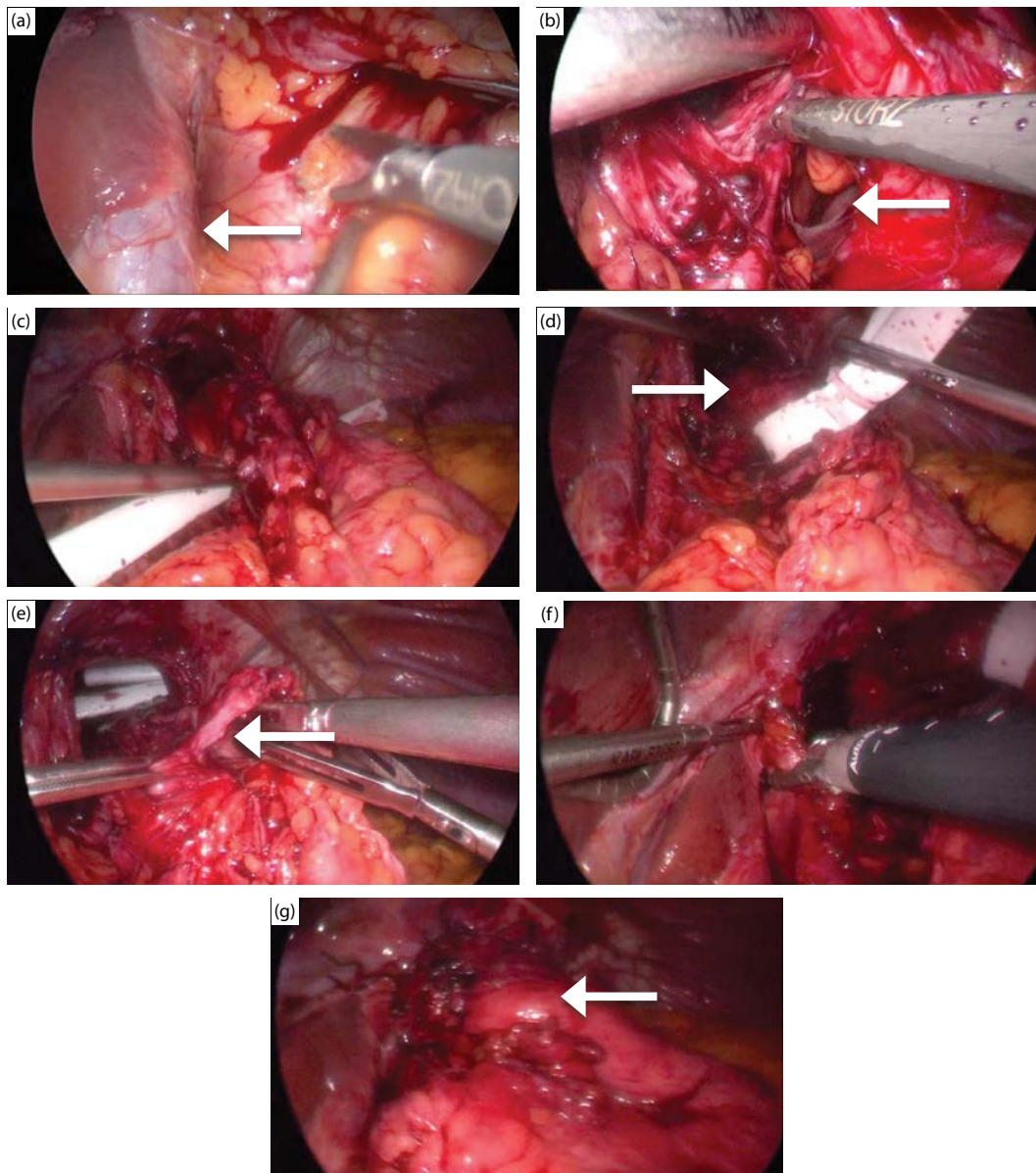


Figure 52.5 Techniques of reoperative hiatal surgery. These images highlight dissection techniques used in a 71-year-old woman 8 months after paraesophageal hernia repair with Nissen fundoplication who presented with dysphagia due to Type I hiatal hernia recurrence. (a) Dissection begins along the right crus to gain a plane in the chest and begin bringing down the wrap. Inferior vena cava (arrow). (b) Posterior dissection along the left crus and exposure of the retrogastric window (arrow). (c) Use of Penrose drain to facilitate retraction. (d) Confirmation of adequate esophageal length (arrow). (e) Undoing of previous fundoplication to reestablish normal anatomy (arrow). (f) Crural closure. (g) Final view showing fundoplication, in this case, an anterior 180° wrap (arrow). Refer to [Video 52.1](#) for more detail.

encircled by a Penrose drain in the chest above the level of the dense hiatal adhesions ([Figure 52.5](#) and [Video 52.1](#)). Traction applied by the assistant can greatly help define dissection planes. In the case of a tight hiatus where it is difficult to enter the mediastinum, the crura can be opened to make room for dissection. We favor opening the crura anteriorly in the midline, between the inferior phrenic vessels, as this area provides the least chance of injury to other structures, and the crural edges can be reapproximated relatively easily. The value of intraoperative endoscopy during

dissection cannot be overemphasized (see previous discussion).

For all redo cases, regardless of the indication or approach, the initial operative goals should be to mobilize the GE junction into the abdomen and completely take down any previous fundoplication. Once normal anatomy is reestablished, the decision can be made regarding hiatal re-repair, type of fundoplication to be used (if any), need for gastropexy, and/or need for an esophageal lengthening procedure (see “Management of intraoperative complications” section).



Management of intraoperative complications

Several complications can occur during reoperative hiatal surgery. The most common include gastric or esophageal perforation and pneumothorax.

GASTRIC AND ESOPHAGEAL PERFORATIONS

Most gastric perforations occur as a consequence of undoing the prior fundoplication and can be repaired primarily or by stapled wedge fundectomy. If the esophagus is injured, treatment depends on the location of the perforation, the extent, and the cause (cold or hot dissection). Before attempting repair, the extent of injury must be determined (ideally both operatively and by endoscopy) and the esophagus sufficiently mobilized to allow repair without tension. An iatrogenic perforation with cold scissors, where the wound edges can be brought together easily, in an otherwise nondiseased esophagus can be safely repaired primarily. If possible, an attempt should be made to cover the repaired esophageal perforation by the fundoplication. Mesh erosion, loss of esophageal wall, perforation by thermal energy, or delayed presentation are complex situations that extend beyond the scope of this chapter and warrant consultation with an expert esophageal surgeon.

PNEUMOTHORAX

Iatrogenic pleural entry causing carbon dioxide pneumothorax rarely requires intervention. If ventilation or hemodynamics are significantly compromised, reduction of CO₂ insufflation pressures to 8–12 mm Hg can usually temporize the problem until case completion. If the patient cannot tolerate sustained CO₂ insufflation even at low pressures, the case may need to be converted to laparotomy. Pneumothoraces caused by pleural breach without injury to the lung parenchyma resolve quickly after release of pneumoperitoneum and rarely require chest tube insertion.

SPECIAL CONSIDERATIONS

Short esophagus

Short esophagus is defined as an inability to obtain 2–3 cm of tension-free esophagus below the hiatus, despite extensive mediastinal esophageal dissection.¹⁸ The incidence of short esophagus is controversial,^{19,20} but it has been related to chronic inflammation and large, long-standing type III paraesophageal hernias.²¹

Short esophagus may be a cause of recurrent herniation after a primary repair and, if encountered during reoperation, performance of an esophageal lengthening procedure should be seriously considered, with the Collis-Nissen the most widely accepted technique.^{22,23}

Acute recurrent hiatal hernia with organ ischemia

In rare cases, acute hiatal hernia recurrence may occur early in the postoperative period leading to gastric volvulus,

obstruction, and ultimately, ischemia. Early recognition and reoperation are crucial to avoid gastric necrosis. The classic presentation includes retrosternal chest pain, retching without vomiting, inability to pass a nasogastric tube below the GE junction, and an intrathoracic air-fluid level on chest x-ray. Patient condition and degree of suspicion for gastric ischemia influence the choice of operative approach, but laparoscopic repair can be attempted in stable patients who will tolerate pneumoperitoneum and steep reverse Trendelenburg positioning. Otherwise, since the herniated abdominal organs are those most likely to be compromised, an open abdominal approach is usually preferred over the thoracic approach.

SUMMARY

Indications for and techniques used in reoperative hiatal surgery are complex. Thorough patient assessment and preoperative planning combined with meticulous surgical technique are essential to the success of these operations.

VIDEO

Video 52.1 Video demonstrating key steps and operative approach to revisional hiatal surgery (<https://youtu.be/7v7BuRi0mlg>).

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Laparoscopic treatment of achalasia

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BACKGROUND

Achalasia is a disorder characterized by decreased or absent peristalsis of the body of the esophagus and failure of the lower esophageal sphincter (LES) to relax in response to swallowing. The cause of achalasia is unclear, but it is thought to be due to an immune process that causes a selective loss of inhibitory neurons in the myenteric plexus. Achalasia has also been shown to be associated with a decrease in the synthesis of nitric oxide and vasoactive intestinal polypeptide. Treatment options are aimed at improving the passage of solids and liquids through the gastroesophageal junction but do little to improve peristalsis. Treatment to reverse the pathophysiology of the disease process does not currently exist.

HISTORY

The first successful reported case of esophageal dilatation dates back to the seventeenth century, when Thomas Willis performed an esophageal dilatation using a sponge attached to a whale bone. In 1913, Ernst Heller performed the first successful anterior and posterior myotomy through an open abdominal incision. The procedure was subsequently revised to involve a single anterior incision in 1918 by De Brune Groenveldt and Zaaijer, with good results. Ellis began performing the myotomy through a left thoracotomy in 1958, with decreased incidence of postoperative reflux. Despite the success of surgical myotomy, most patients opted for nonsurgical approaches to treatment such as dilatation, prior to the advent of minimally invasive surgery. The more morbid open operation was reserved for patients who had failed prior nonoperative therapy.

Pellegrini was the first to perform a minimally invasive myotomy in 1992, which he performed thoracoscopically. Shortly after, Cuschieri performed the first laparoscopic

myotomy, which has become the most widely accepted operation for the treatment of achalasia today.

In 2008, Inoue performed the first peroral endoscopic myotomy (POEM), a procedure that has been gaining significant popularity as an alternative to laparoscopic myotomy for the treatment of achalasia. Recent data estimate that one out of every four patients with achalasia is being treated with POEM, and this number continues to grow. Intermediate-term follow-up data are promising; however, data regarding the long-term efficacy of POEM are lacking.

DIAGNOSIS

Presentation

Typical symptoms associated with achalasia include dysphagia, odynophagia, progressive chest pain, weight loss, regurgitation, aspiration, and cough. Although all of these symptoms may be associated with this condition, they are not unique to achalasia, so many patients are misdiagnosed with other conditions such as gastroesophageal reflux disease, gastroparesis, or other esophageal motility disorders.

The most common complaint in achalasia is dysphagia to both solids and liquids (more often cold than hot) and regurgitation of saliva or undigested food. The presence of these symptoms may not be conclusive but should help guide the clinician to seek further diagnostic workup.

Diagnostic tests

The diagnostic workup for suspected achalasia consists of esophagogastroduodenoscopy (EGD), esophageal manometry, and contrast esophagram, which is the best initial

screening test for suspected achalasia. Esophagram typically shows a loss of primary peristalsis and some degree of esophageal dilation with smooth tapering of the lower esophagus, described as the classic “bird’s beak” appearance. As the disease progresses, the esophagus may dilate further and become tortuous or kinked, a condition known as sigmoid esophagus. Occasionally, an epiphrenic diverticulum may also be present, which is caused by an increase in esophageal pressure associated with achalasia. Contrast studies have been considered diagnostic in up to two-thirds of patients.

Upper endoscopy should be performed when achalasia is suspected. EGD may help to rule out pseudoachalasia, where an esophageal tumor or primary peptic stricture narrows the lower esophageal lumen and provides similar manometric findings to achalasia. Pseudoachalasia should be suspected in elderly patients who present with excessive weight loss and a short duration of symptoms. In patients suspected of having pseudoachalasia, endoscopic ultrasound may be a useful to determine invasion of tumor and abnormal-appearing lymph nodes. As reflux may be associated with achalasia, an EGD can screen for early tumors or Barrett esophagus and help guide further investigations and follow-up.

The “gold standard” for the diagnosis of achalasia is esophageal manometry. Classic manometric findings include incomplete or absent LES relaxation, lack of peristalsis of the esophageal body, and an elevated LES resting pressure. Manometry has been shown to be diagnostic for achalasia in 90% of cases.

The Chicago classification for esophageal motility disorders is based on information provided by high-resolution esophageal pressure topography (HREPT). HREPT combines high-resolution manometry and esophageal pressure topography, which enables the development of standardized objective measurements of esophageal peristaltic and sphincter function. There are three subtypes of achalasia based on the Chicago Classification scale. Type I achalasia (classic achalasia) is defined as having an elevated median integrated relaxation pressure (IRP) with 100% failed peristalsis. Type II achalasia (achalasia with esophageal compression) is defined as an elevated median IRP, 100% failed peristalsis, and panesophageal pressurization with greater than 20% of swallows. Type III achalasia (spastic achalasia) is also defined as having an elevated IRP with no normal peristalsis, but with premature (spastic) contractions with a distal contractile integral (DCI) greater than 450 mm Hg with greater than 20% of swallows. Patients with type III achalasia often have symptoms related to spasm and have a lower response rate to a limited myotomy.

NONSURGICAL MANAGEMENT OF ACHALASIA

Medical therapy has a limited role in the treatment of achalasia. Calcium channel blockers and long-acting nitrates

that act on smooth muscle can be effective in reducing LES pressure and providing temporary relief of dysphagia in a small subset of patients with very mild achalasia, but little benefit has been shown in patients with more severe forms of the disease. The effects of these medications are short-lived and provide incomplete symptom relief, because they do not improve LES relaxation or peristalsis. Because of limited effectiveness, drug treatment is usually reserved for patients who are too high risk; those who refuse other, more aggressive therapies; or those with type III achalasia where spasm is the major component.

Botulinum toxin (Botox) injections have also been used to treat achalasia. This is injected endoscopically into the LES, causing relaxation of the sphincter. Botox has an initial efficacy rate of 65%–75%; however, because the effect gradually wears off after 1–4 months, repeat injections are often required. With repeated injections, this becomes less effective over time. Thus, success rates for Botox alone are about 25% at 1 year. Additionally, Botox injections may cause scarring of the submucosa. This can affect future surgical dissection and increase the risk of perforation during surgical myotomy. Botox is generally reserved for patients at high surgical risk, who prefer not to undergo more aggressive therapies, and occasionally for diagnosis.

Endoscopic pneumatic dilation is an established treatment for achalasia. A pneumatic dilation balloon is placed across the LES and inflated to 7–15 psi for 15–60 seconds. Symptomatic relief at 1 year is seen in 70% of patients, making this treatment modality more effective than Botox injections, but multiple sessions may be required. Complications are rare, but perforation can occur in up to 4% of patients. Because of this potential, many endoscopists perform esophageal contrast swallow studies prior to discharge to rule out perforation, which might require a thoracotomy for repair if detected. Long-term efficacy is approximately 50% at 5 years.

POEM has emerged as an alternative to laparoscopic myotomy. The circular muscle layer of the esophagus is divided through a mucosotomy and submucosal tunnel. Because of its even less invasive approach and lack of external scarring when compared to laparoscopic myotomy, this is gaining popularity as a primary treatment for achalasia. Long-term data are lacking, and the documented incidence of reflux associated with the procedure may limit widespread use. However, certain patients with type III achalasia may have better symptomatic relief with POEM when compared to a more limited laparoscopic myotomy, and this approach may be useful in those with morbid obesity or a previously operated hiatus.

SURGICAL MANAGEMENT OF ACHALASIA

Originally named after Ernst Heller, who performed the first successful open myotomy in 1913, surgical myotomy for the treatment of achalasia remains the gold standard of treatment today. Open thoracic or abdominal approaches

are generally reserved for re-operations or for those with multiple prior upper abdominal procedures.

Laparoscopic Heller myotomy

PREOPERATIVE CONSIDERATIONS

Patients should start a clear liquid diet 1–2 days prior to the operation. As they have some degree of obstruction, a clear liquid diet will reduce the amount of retained food in the esophagus, lowering the risk of aspiration and facilitating upper endoscopy.

Sequential compression stockings and subcutaneous heparin should be used to reduce the risk of deep vein thrombosis. Preoperative intravenous antibiotics to cover against upper gastrointestinal flora should be administered in case of possible perforation or spillage of gastrointestinal contents. A urinary catheter can be placed when a prolonged procedure is anticipated or for patients who are at high risk of urinary retention.

We prefer the patient to be positioned on a cushioned bean bag in the low lithotomy position, using Allen stirrups, or on a split leg table. The operating surgeon is positioned in between the legs. An assistant stands to the left of the patient, while the camera operator stands on the right. Monitors are positioned at the head of the bed, to either side of the patient.

A flexible endoscope is required, as endoscopy is routinely performed intraoperatively to assess the myotomy length and to rule out perforation. Upper endoscopy may be performed early to clear out secretions or food, identify the distance to the LES, and evaluate the degree of esophageal obstruction.

TECHNIQUE

Five trocars will be utilized and organized similar to the arrangement for a laparoscopic fundoplication. Long-acting local anesthesia should be injected into the skin prior to trocar insertion to aide in postoperative analgesia.

An open technique is used to access the peritoneal cavity 12 cm below the xiphoid, using a 12-mm port. The abdomen is then insufflated to 15-mm Hg. A 30° laparoscope is inserted through the port after insufflation. A 5-mm port is then placed in the left midclavicular line at the same level as the camera port. This port will be used by the assistant to help with retraction. A 12-mm dilating port is then placed a few centimeters below and to the left of the xiphoid just under the costal margin. Another 12-mm dilating port is placed at the right anterior axillary line at the same horizontal level as the first and second ports, to be used for the liver retractor. Finally, a 5-mm port is placed a few centimeters below and to the right of the xiphoid as an additional working port (**Figure 53.1**).

The patient is placed in the reverse Trendelenburg position to allow for gravity to assist in retraction. The liver retractor is inserted through the right lateral port and left lateral segment of the liver retracted, exposing the caudate lobe, gastrohepatic ligament, and hiatus. The gastrohepatic

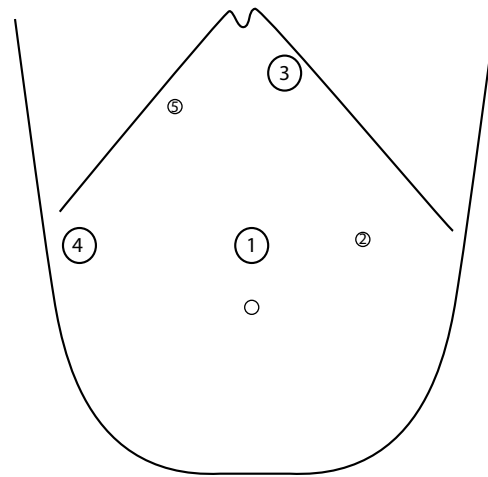


Figure 53.1 Port placement. 1, camera port; 2, left midclavicular port; 3, left upper port; 4, right lateral port; 5, right 5 mm port.

ligament is identified along the caudate lobe and divided toward the diaphragm, exposing the right crus. After the phrenoesophageal ligament is opened, both crura of the diaphragm and the anterior vagus nerve are identified.

The right crus is retracted laterally to expose the esophagus and posterior vagus. A plane is then developed posterior to the esophagus and posterior vagus nerve, freeing the esophagus from the left crus on the opposite side. Dissection only needs to be extensive enough to allow for passage of a grasper behind the esophagus. A grasper is then passed through this plane and a Penrose drain is pulled back behind the esophagus to encircle both the esophagus and vagus nerves. The Penrose drain will be used to provide gentle anterior and caudal traction to the esophagus to allow for dissection into the mediastinum in order to extend the myotomy well above the gastroesophageal junction. Dissection is carried up the right crus to where the anterior vagus can be seen and preserved. The anterior mediastinum is dissected to allow for a 5-cm myotomy.

The gastrosplenic ligament may be divided with ultrasonic scissors if a Toupet fundoplication is anticipated. The gastroesophageal fat pad should be removed on the right anterior surface of the esophagus, in between the anterior and posterior vagus nerves to gain better exposure of the gastroesophageal junction.

We place a 52-Fr bougie into the esophagus, which helps with identification of the esophagus by palpation, puts the fibers under tension, and provides support for blunt dissection. The gastroesophageal junction is usually where the myotomy begins. The esophagus is grasped by the surgeon on the right side, anterior to the posterior vagus nerve. The assistant then grasps the esophagus more to the left and anteriorly, but still to the right of the anterior vagus nerve, providing countertraction on the longitudinal muscle layer and bringing it further into the abdomen. The longitudinal muscle layer is then gently divided using

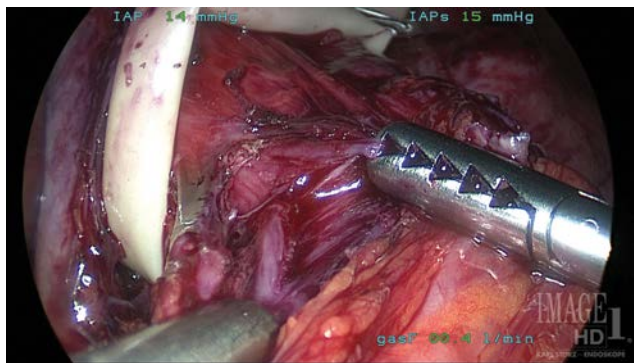


Figure 53.2 Division of longitudinal muscle layer, exposing circular muscle layer.

a combination of blunt dissection, ultrasonic scissors, and countertension (**Figure 53.2**).

The circular muscle layer is then identified underneath the cut longitudinal fibers and carefully divided with a combination of sharp and blunt dissection using the ultrasonic scissors or suction device. If the ultrasonic scissors are used for blunt dissection, care must be taken as the blade can remain hot for a while after activation and can damage the mucosa. The esophageal mucosa should be clearly identified after division of the circular muscle layer as the dissection is carried cranially and caudally. The plane in between the circular muscle and mucosa should easily separate with blunt dissection. The muscle can then be divided with the ultrasonic scissors. The myotomy should be carried up 5 cm above the gastroesophageal junction and then 2 cm below onto the cardia of the stomach. This part of the dissection is more difficult because the muscle is relatively thin and consists of more tenacious sling fibers. It may be useful to know the length of the tips of commonly used instruments as they can be used to measure the length of your myotomy. A good landmark to assure the myotomy extends sufficiently onto the stomach is the first gastric vein. After completion of the myotomy, the mucosa should bulge through the myotomy incision (**Figure 53.3**).

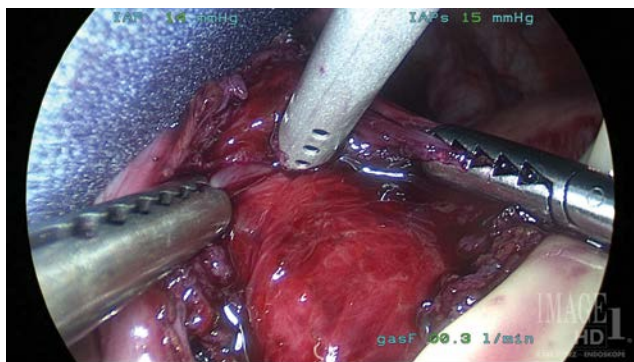


Figure 53.3 Esophageal mucosa bulging through cut myotomy.

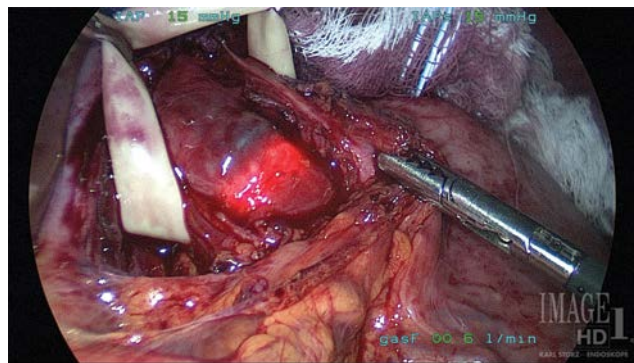


Figure 53.4 Endoscopic evaluation of myotomy.

Endoscopy is used to exclude injury and confirm adequacy of myotomy and exclude mucosal injury (**Figure 53.4**). Underwater air insufflation should be performed to confirm the absence of a leak. If a perforation is detected, it should be repaired primarily with 3–0 absorbable sutures. The myotomy should then be performed on the opposite side, and the repair should be buttressed with an anterior fundoplication.

If there is a significant hiatal defect, the crura should be reapproximated. This can be done by placing posterior sutures. With larger hiatal defects, several anteriorly placed sutures may be necessary to prevent excessive angulation of the esophagus at the hiatus.

A fundoplication is generally performed. A partial fundoplication is sufficient in reducing the incidence of reflux while avoiding the risk of dysphagia. A full fundoplication (Nissen) should not be done due to a high incidence of dysphagia. Dor and Toupet fundoplications are common antireflux procedures performed along with the myotomy. The decision is left to the surgeons' preference and the situation.

For a Toupet fundoplication, the fundus is brought posterior to the esophagus along the plane of previous dissection. The right limb of the fundus is then sutured to the right crus and then the edge of the myotomy with three interrupted 2–0 sutures. The left limb of the fundus is sutured to the left crus and then the edge of the myotomy creating a 270° wrap. This repair requires more time and gastric mobilization. It may cause excessive anterior angulation of the esophagus, especially in cases with sigmoid esophagus, leading to dysphagia.

A Dor fundoplication is a partial anterior wrap. The posterior wall of left fundus is first sutured to the left edge of the myotomy with interrupted 2–0 sutures. The remainder of the fundus is then brought anteriorly overlying the esophagus and is sutured to the right edge of the myotomy and the right crus with interrupted 2–0 sutures. This involves less mobilization of the fundus and may be helpful in protecting an esophageal repair. Concerns about scarring and recurrence have been raised but are not clear.

We prefer a modified fundoplication, which secures the fundus to the anterior left and right crura and to the cut

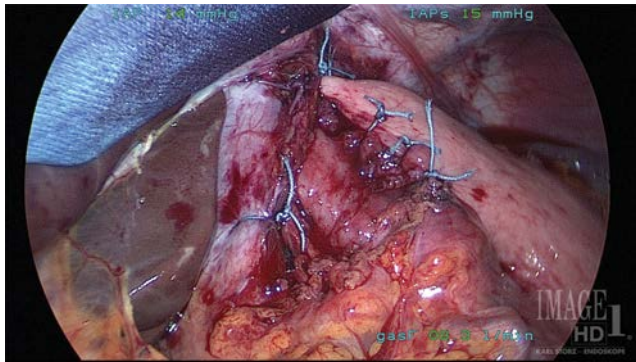


Figure 53.5 Partial fundoplication.

edge of the myotomy on the left side. This recreates the angle of His, keeps the myotomy open, and provides a partial fundoplication (**Figure 53.5**).

Prior to closure, hemostasis is achieved, a nasogastric tube is placed under laparoscopic guidance and the ports are removed under visualization. The camera port fascia is closed with interrupted suture and skin is closed with absorbable suture. The additional 12-mm ports need not be closed because of the use of dilated ports and their proximity to the costal margins.

POSTOPERATIVE CARE

Subcutaneous heparin and sequential compression stockings are continued postoperatively. Patients are maintained with nothing by mouth, with nasogastric suction for the first postoperative night. On the morning of postoperative day 1, the nasogastric tube is removed, and oral intake is advanced as tolerated. Unless a patient is having difficulty swallowing, routine postoperative contrast swallow studies are not necessary. Patients are usually discharged on the first postoperative day.

COMPLICATIONS

Laparoscopic Heller myotomy is a relatively safe operation with low morbidity and mortality. Despite this, complications can arise without proper operative planning and execution.

Because patients often present with dysphagia and varying degrees of obstruction, they are at higher risk of aspiration due to the potential of having retained food in the

esophagus. To minimize this risk, a liquid diet for 24–48 hours preoperatively will reduce the amount of particulate matter within the esophagus and lower the risk of aspiration. Care must be taken at time of induction to minimize this potential complication.

Incomplete myotomy can result in recurrent dysphagia. It is important to remember to extend the myotomy at least 2 cm onto the stomach. The first gastric vein can be used as a landmark. Also, intraoperative endoscopy can assist in visualizing the myotomy as it extends onto the stomach. Recurrent dysphagia can also result as a consequence of the fundoplication. A full fundoplication is associated with a higher incidence of dysphagia than partial fundoplication.

Intraoperative esophageal perforation can occur in up to 10% of patients. Perforation is more common in patients who have scarring due to prior procedures. Improper use of surgical energy devices can cause inadvertent injury, which may also lead to perforation. Care should be taken when placing nasogastric or bougie tubes, especially after myotomy is performed, and should be placed under laparoscopic guidance.

CONCLUSION

Although many therapies exist for the treatment of achalasia, laparoscopic Heller myotomy with partial fundoplication remains the treatment of choice. Endoscopic myotomy has shown promise in recent studies, but long-term data are still lacking.

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Robotic approach to achalasia

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INTRODUCTION

Achalasia is an uncommon esophageal motility disorder with an annual incidence of approximately 1.6 cases per 100,000 individuals in North America and is characterized by the absence of esophageal peristalsis and impaired relaxation of the lower esophageal sphincter (LES) in response to swallowing.¹ The physiopathology of this disease is not well understood, but there is suggestion that changes at the level of the intramuscular neuronal plexus of the esophagus lead to the clinical abnormalities characteristic of achalasia. The inability of the esophagus to normally empty ingested food into the stomach causes dysphagia, regurgitation, and sometimes chest pain that can lead to weight loss and esophageal dilation.

The first reports available of surgical treatment for achalasia were by Dr. Ernest Heller in early 1913.² Until the advent of minimally invasive techniques, the standard treatment for esophageal diseases was via open methods, either through an abdominal or more commonly a thoracic approach. Unfortunately, the rates of dysphagia due to short myotomy and the resulting acid reflux due to inability to perform a fundoplication via the transthoracic route were extremely high.

Despite evidence showing that open surgery was the most reliable way to obtain long-term relief from dysphagia with the fewest side effects, the morbidity and discomfort associated with the thoracotomy or laparotomy dampened enthusiasm for this operation, leading to the proliferation of other methods. These methods, including pneumatic dilation and botulin toxin (Botox) injection to the lower esophageal sphincter, although less effective, were perceived to be “less invasive” and better tolerated.

Minimally invasive approaches for achalasia were first transthoracic and later transabdominal. The thoracoscopic approach yielded good results for dysphagia but had extremely high rates of symptomatic and asymptomatic

reflux disease due to the inability to perform an adequate antireflux procedure at the time of the myotomy.³ The laparoscopic approach was introduced as a solution, with its easy access to the gastroesophageal junction (GEJ) allowing the performance of a long myotomy extending into the mediastinum and continuing at least 2 cm into the stomach.⁴ The ability to add an antireflux procedure during esophageal surgery and thereby prevent unacceptably high rates of acid reflux was of paramount benefit.

In 2000, the da Vinci operative robotic system (Intuitive Surgical Corporation, Sunnyvale, California) entered the market. Our group's first robotic Heller myotomy was performed in September 2000 and the first report of robotic surgery for achalasia was available in 2001.⁵ This approach emerged as an alternative to the laparoscopic technique, providing improved visualization and better fine motor control allowing creation of a complete surgical myotomy with greater accuracy and a lower rate of esophageal mucosal injury. One potential disadvantage of the robotic system is the lack of haptic feedback that impedes determination of the amount of pressure exerted on tissues that can potentially cause inadvertent injuries.

Studies comparing laparoscopic techniques with robotic Heller myotomy showed no significant difference in terms of dysphagia, reflux, heartburn, and quality of life after surgery. The robotic approach, however, consistently showed significantly fewer esophageal mucosal perforations but a trend toward prolonged operative times and higher costs.^{6–10}

DIAGNOSIS OF ACHALASIA

The diagnosis of achalasia is made based on symptoms and diagnostic studies. The most frequent symptom is dysphagia to solids and liquids that occurs in approximately 90%–100% of patients. Regurgitation is reported in approximately 60% of patients. Heartburn and occasional chest pain with or

without weight loss are present in approximately 50% of patients.^{4,11} Heartburn that does not respond to adequate proton pump inhibitor therapy should raise the suspicion of achalasia.¹²

All patients are evaluated with an upper gastrointestinal barium swallow, esophagogastroduodenoscopy, and esophageal manometry.

The upper gastrointestinal barium swallow typically shows the presence of esophageal dilation, sometimes with tortuosity of the esophagus and the characteristic “bird’s beak” tapering of the distal esophagus.

This is followed by esophageal manometry, which is the definitive diagnostic tool. In general, manometry reveals failure of relaxation of the LES and absence of esophageal peristalsis.

An esophagogastroduodenoscopy is performed to rule out other diseases such as pseudoachalasia, neoplasm, or other esophageal disorders.

EFFECT OF PREVIOUS TREATMENT ON HELLER MYOTOMY

The literature available is inconclusive about the outcomes of Heller myotomy on patients who underwent prior endoscopic therapies for achalasia, but several studies have suggested an increased risk of intraoperative complications.¹³ Prior endoscopic treatments are not a contraindication to the robotic approach; in fact, robotics take advantage of three-dimensional (3D) visualization and can improve dissection through scarred and inflamed tissue planes caused by previous procedures.

PREPARATION FOR SURGERY

Depending on preoperative nutritional status, patients may be placed on a hypocaloric liquid diet for 3–5 days before surgery. This promotes a clean and less dilated esophagus and may help to decrease the size of the liver, which improves visualization of the operative field and helps to prevent injury-related bleeding.

OPERATIVE TECHNIQUE

The patient is placed on the operative room table in a split leg position, secured in place with special straps across both legs and lower abdomen.

The robotic console is located at the right side of the patient and the robotic arms are docked over the left side of the patient. The scrub nurse and the first assistant are located on the left side of the patient (**Figure 54.1**). A five-port technique is used. The first port used to access the abdomen is a 12-mm optical trocar. This trocar is positioned 2 cm to the left of the umbilicus, approximately two finger-breaths

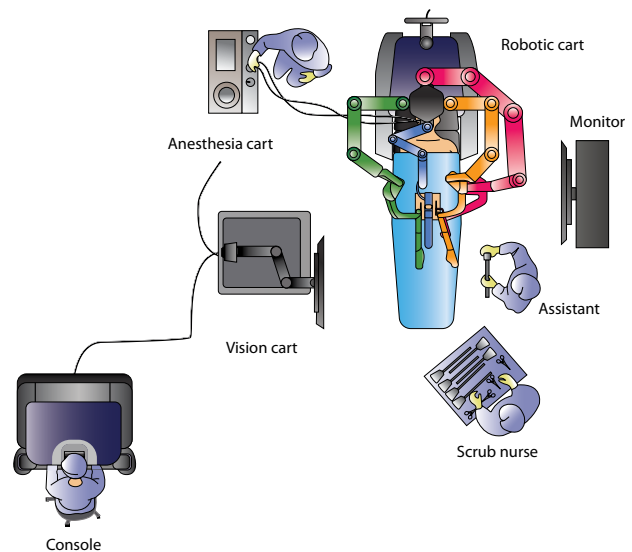


Figure 54.1 Operative room setup for robotic-assisted laparoscopic Heller myotomy.

above the umbilicus. Pneumoperitoneum is induced to a pressure of 12–15 mm Hg. Another two 8-mm robotic trocars are placed, one in the right upper quadrant and the other in the left upper quadrant, both in the midclavicular line. A 0.5-cm incision is made in the subxiphoid area and the left lobe of the liver is retracted anteriorly using a liver retractor. A 12-mm assistant port is placed in the left anterior axillary line 2 cm below the costal margin (**Figure 54.2**).

The patient is then positioned in steep reverse Trendelenburg position. With the aid of nursing personnel, the robotic surgical cart is approximated to the patient over the left shoulder. The setup of the robot is performed by the assistant at the bedside.



Figure 54.2 Port placement for robotic-assisted laparoscopic Heller myotomy with daVinci Si model. (A, assistant port; C, camera; N, Nathanson liver retractors; R1, robotic arm #1; R2, robotic arm #2.)

A 0° angle scope is introduced into the 12-mm port. Under direct camera vision, a right-handed cautery hook and left-handed fenestrated bipolar forceps are introduced. The assistant will be in charge of cutting, suctioning, and retracting. For this reason, training in basic laparoscopic surgery and robotics is essential for the first assistant.

The left crura approach is routinely used. The operation begins by taking down the proximal short gastric vessels with ultrasonic shears. Beginning approximately at the level of the caudate lobe of the liver and continuing cephalad to the crura, the fundus is completely mobilized from its posterior attachments to the anterior capsule of the pancreas allowing a tension-free partial fundoplication. The left and right crura are then dissected anteriorly, respecting the posterior attachments. The posterior mediastinum is entered, and dissection continues laterally and anteriorly to expose the lower third of the esophagus. The gastrohepatic and the phrenoesophageal ligaments are divided. The right crura is identified and dissected away from the esophagus. A 44 Fr bougie is passed through the patient's mouth by the anesthesiologist or a surgical team member to aid in stabilization of the esophagus during the myotomy. The gastric fat pad is removed to better expose the GEJ (**Figure 54.3**). The anterior branch of the vagus nerve is identified and dissected off the anterior wall of the esophagus. The assistant applies gentle tension over the GEJ with an atraumatic grasper to allow exposure of the lower esophagus (**Figure 54.4**). With hook electrocautery, the area of the myotomy is marked (**Figure 54.5**). An anterior myotomy is performed starting just above the GEJ at the 12 o'clock position using the robotic articulated hook electrocautery. This is performed with a combination of gentle electrocoagulation over the muscular fibers and blunt dissection with medial to lateral motion using the hook to transect the muscular fibers. The bipolar forceps

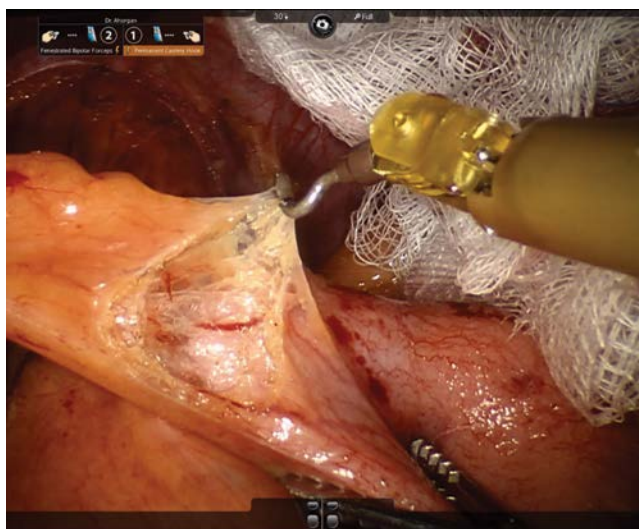


Figure 54.3 Fat pad dissection that allows exposure of the GEJ.

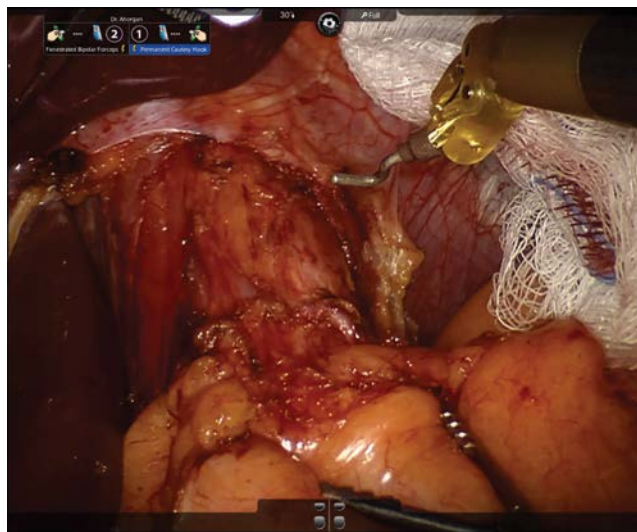


Figure 54.4 Dissection of the crura and exposure of anterior esophagus. Gentle downward traction is performed by the assistant with an atraumatic grasper to expose the GEJ.

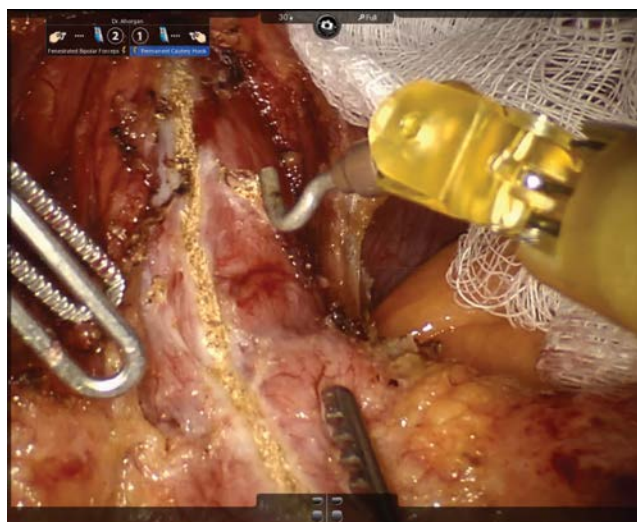


Figure 54.5 The extension of the myotomy is marked with hook electrocautery.

are used to grasp the right side of the muscular fibers and give lateral tension to facilitate the hook dissection. A sponge is used to hold pressure and achieve hemostasis over the submucosa. After the submucosal plane is reached, the myotomy is extended to a minimum of 6 cm proximally and 2 cm distally into the stomach (**Figures 54.6 and 54.7**). The robotic 3D view allows improved visualization of single muscle fibers that may not be distinguished under laparoscopic view.

After this, either an anterior 180° fundoplication (Dor fundoplication) or posterior 270° partial fundoplication (Toupet fundoplication) is performed. We prefer the Dor fundoplication since in addition to protecting against

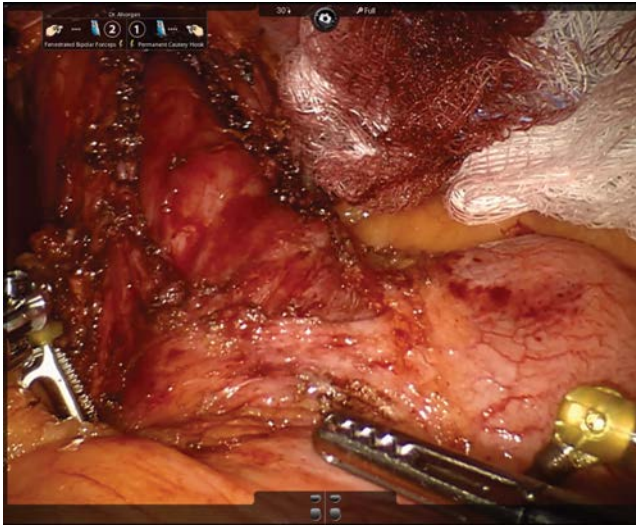


Figure 54.6 Completed myotomy with submucosal plane visualization.



Figure 54.7 Visualization of completed myotomy with preserved anterior vagus nerve.

gastroesophageal reflux, it provides coverage to the exposed submucosa of the esophagus, which may prevent the development of a fistula if this layer suffers an inadvertent thermal injury during the course of the operation. Critics of this approach argue that this may also act to reapproximate the edges of the myotomy, hampering its efficacy in relieving dysphagia. The Dor fundoplication consists of two rows of sutures using 2.0 silk on a noncutting needle. The suture length is about 15 cm. The first row of sutures includes three stitches that are placed from the superior to the inferior portion of the myotomy. The first stitch includes the gastric fundus, the left crura, and the left side of the myotomy. The following two stitches are placed at similar intervals to allow complete coverage of the myotomy and include the gastric

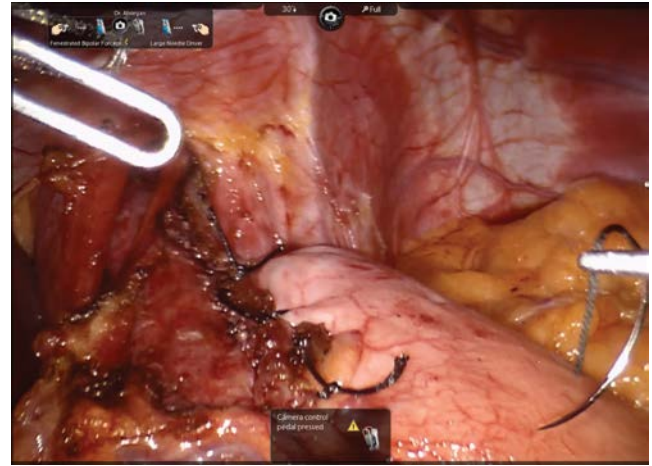


Figure 54.8 Dor fundoplication creation with first row of sutures over the left side of the myotomy.

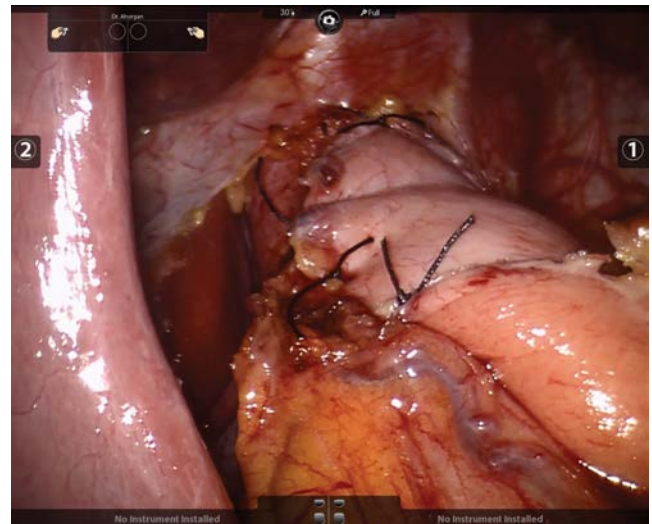


Figure 54.9 Final view of the completed Dor fundoplication.

fundus and the left side of the myotomy (**Figure 54.8**). Next, the fundus is folded over the myotomy and, with the help of the assistant to hold the fundus in place, a second row of sutures is placed. This second row of sutures is created by placing three or four stitches between the stomach and the right edge of the myotomy to allow coverage of all the exposed submucosa. The first stitch of this row should also include the right crura (**Figure 54.9**). An upper endoscopy is performed at the completion of the procedure to assess the patency of the GEJ as well as confirm postoperative anatomy.

POSTOPERATIVE CARE

All patients are admitted to a medical surgical unit and are allowed sips of clear liquids the day of the procedure.

Pain control is achieved with intravenous nonsteroidal anti-inflammatory drugs and acetaminophen as needed. Antiemetic medication is ordered to avoid early postoperative vomiting and retching. On postoperative day 1, patients are advanced to a full liquid diet and are discharged on postoperative day 1 or 2, depending on pain control and diet tolerance. Esophagogram is ordered on an as-needed basis if the patient develops concerning signs or diet is not able to be advanced as expected. A full liquid diet is maintained for the first 2 weeks. Avoidance of foods that may cause irritation allows healing of the myotomy and lessens the chance of perforation in the operated area. The diet is advanced to a blended diet from week 2 to 4. At 4 weeks, solid food is slowly introduced, avoiding red meats and bread. At 6 weeks, there is no food restriction and the patient is instructed to slowly introduce solid food with specific instructions to thoroughly chew meats and follow all solids with liquids. The patient is seen in the office at 2 and 6 weeks, again at 2 months, and yearly thereafter. Most patients report significant improvement of symptoms after surgery.

COMPLICATIONS

Complications can be divided into early (within 30 days of the procedure) and late.

Early complications

ACCESS AND INADVERTENT INTRA-ABDOMINAL INJURIES

Similar to laparoscopic surgery, robotic access complications may be encountered, which can include perforation of intra-abdominal viscera and bleeding. These can be minimized with good technique and appropriate initial access site selection. Furthermore, the surgeon should be aware of the lack of haptic feedback from the robotic instruments as well as the narrower field of view when comparing with laparoscopy that may predispose to increased risk of inadvertent intra-abdominal viscera injuries. This can be prevented by maintaining instruments within direct camera view at all times.

BLEEDING

Bleeding is more likely to occur during the creation of the myotomy due to the preferential use of blunt dissection to avoid the use of energy that could potentially increase the risk of inadvertent or delayed esophageal mucosal injury. A careful dissection should be undertaken, and manual pressure with surgical gauze can be used to achieve hemostasis.

MUCOSAL PERFORATION

The rate of mucosal perforation for the laparoscopic approach has been variously reported to be between 1% and 15%.^{14,15,16} The robotic-assisted approach has consistently demonstrated that this risk can be decreased

by the high-definition optics of the 3D robotic camera and fine dissection instruments. If perforation occurs, early recognition is crucial, and repair with an absorbable suture should be performed. This type of repair can be challenging with the laparoscopic approach, potentially necessitating conversion to open surgery. The robotic approach can eliminate these shortcomings associated with laparoscopic surgery, resulting in a more durable repair and improved outcomes.

Late complications

DYSPHAGIA

The incidence of dysphagia secondary to incomplete myotomy is significantly lower with the minimally invasive intra-abdominal approach, allowing performance of a longer gastric myotomy, at least 2–3 cm. No differences have been found in outcomes between the laparoscopic and robotic-assisted approaches.¹⁶ Early and late dysphagia have also been reported in patients after total fundoplication; therefore, partial fundoplication, either Dor or Toupet, is advocated.

GASTROESOPHAGEAL REFLUX

Chronic gastroesophageal reflux can cause severe esophageal damage, and some studies have suggested this as the reason for poor long-term outcomes.¹⁷ The rate of esophageal reflux after Heller myotomy has been reported to be approximately 31.4% and as high as 60% in patients without fundoplication and significantly lower at 8.8% (0%–44%) in patients with any type of partial fundoplication, including Dor or Toupet.^{18,19}

OUTCOMES

The primary goal of achalasia surgery is to reduce the pressure at the lower esophageal sphincter in order to relieve the functional obstruction caused by it, allowing feeding by gravity and preventing the complications of chronic functional esophageal obstruction. Although various preoperative and patient disease characteristics have been postulated as predictors of successful outcomes, there is no clear evidence in the literature about which patients will benefit the most from the procedure. Outcomes comparing laparoscopic and robotic techniques have reported similar results in terms of morbidity, mortality, intensive care unit admissions, length of hospital stay, and 30-day readmissions.¹⁰ The rate of dysphagia resolution with both approaches is reported to be around 90% in the short term, with most patients satisfied with their outcome.^{6,7,20} The most significant difference and constant finding differentiating the two approaches has been the rate of esophageal mucosal perforation, which has been found to be significantly lower with the robotic-assisted technique.^{6,7,11,15,20}

Long-term data after robotic-assisted Heller myotomy are limited. A single retrospective study has shown similar

outcomes when compared to the laparoscopic approach.¹⁵ It is reasonable to predict that similar and possibly better long-term results are to be expected when comparing the robotic-assisted to the laparoscopic approach due to several procedural advantages that include better ergonomics, better visualization, and the possibility of finer dissection while maintaining the same surgical principles of the laparoscopic operation.

The drawback of the robotic procedure is that the cost of the surgery can be significantly higher, especially at the beginning of the experience when the operative times are usually longer when comparing with the laparoscopic approach.¹⁰

Longer-term follow-up is needed to confirm the durability of the robotic-assisted approach.

CONCLUSION

The introduction of robotic techniques for esophageal surgery has improved procedural outcomes, although no differences have been seen in terms of achalasia symptom resolution in the short and long term. Better visualization, ergonomics, and fine instrument motion control allow a more precise dissection during myotomy, previously not achieved with laparoscopic techniques. Larger studies with longer follow-up are needed to confirm the benefits of the robotic-assisted approach. The steady growth and expansion of robotic surgery are opening an exciting spectrum of

possibilities with the application of these new techniques in esophageal surgery.

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Laparoscopic treatment of esophageal diverticula

SARAH E. BILLMEIER AND THADEUS L. TRUS

INTRODUCTION

Esophageal diverticula are uncommon outpouchings of the lumen that can occur at any level of the esophagus. The most common esophageal diverticulum is a Zenker diverticulum located in the cervical esophagus. They can also be found in the midesophagus near the pulmonary hilum or in the distal 10 cm of esophagus, where they are termed *epiphrenic diverticula*. Esophageal diverticula are often asymptomatic; however, when they do result in symptoms, resection is warranted. Open and minimally invasive approaches have been described; however, only epiphrenic diverticula are typically approached via the abdomen, and thus are the focus of this chapter.

BACKGROUND

Esophageal diverticula are classified as either pulsion or traction in etiology. Traction diverticula, typically located in the midesophagus, are caused by granulomatous inflammation of mediastinal nodes and are more common where tuberculosis or histoplasmosis is prevalent. Inflamed nodes adhere to the esophagus and retract over time, creating a conical-shaped true diverticulum (composed of all the layers of the esophageal wall). On barium swallow, traction diverticula tend to have a pointed tip that empties well.¹ Pulsion diverticula are more common and are the result of a motility abnormality distal to the area of the diverticulum that results in elevated intraluminal pressure proximal to an area of functional obstruction. Over time, the esophageal mucosa and submucosa herniate through the musculature to form a false diverticulum. Pulsion diverticula tend to have a wide neck and a rounded contour, and typically retain contrast on barium swallow,² as shown in (Figure 55.1). In the distal esophagus, epiphrenic diverticula are most commonly associated with

achalasia but can also be due to other motility disorders, including diffuse esophageal spasm, hypertensive lower esophageal sphincter, nutcracker esophagus, or a nonspecific motility disorder.³

Zenker diverticulum is a pulsion diverticulum of the hypopharynx usually occurring in elderly populations. They usually present with halitosis, aspiration, and/or symptoms of dysphagia, or globus. Treatment is reserved for patients who are symptomatic. Treatment involves cricopharyngeus (CP) myotomy with or without an invagination for small lesions. Larger diverticula (i.e., 2–6 cm) are usually treated with open diverticulectomy and CP myotomy or endoscopically with diverticulotomy.



Figure 55.1 Epiphrenic diverticulum on barium swallow.

EPIDEMIOLOGY

The true prevalence of epiphrenic diverticula is unknown; however, they are rare. Esophageal diverticula are recognized in less than 1% of all upper endoscopies and are found in 1%–3% of patients with dysphagia.⁴ Less than 10% of all esophageal diverticula are located in the distal esophagus.⁵ Based on radiologic studies, the U.S. prevalence of epiphrenic diverticula is estimated at 0.015%, with most diverticula localized on the right.^{2,6} Incidence of diverticula increases with age, with a peak in the sixth or seventh decade.⁷ One should exercise caution during endoscopy of elderly patients to avoid preferential intubation of the diverticulum, which may result in perforation.

PRESENTATION

Approximately 50%–80% of patients with radiographic evidence of an epiphrenic diverticulum are asymptomatic^{8,9}; however, patients with symptoms most commonly present with dysphagia and regurgitation. Patients may also experience chest pain or heartburn, weight loss, halitosis, and respiratory symptoms including cough, asthma, laryngitis, or recurrent pneumonia from repeated aspiration events.¹⁰ Malignant transformation, bleeding, or perforation are all rare.^{11–13} Symptoms may be attributable either to the diverticulum itself or to the underlying motility disorder. There is little correlation between size of the diverticulum and symptoms.⁸ Heartburn, if present, is often due to stasis and fermentation of food in the distal esophagus, rather than true reflux.¹⁴

DIAGNOSIS AND PREOPERATIVE ASSESSMENT

Physical exam in patients with esophageal diverticula is typically unrevealing. Patients with dysphagia should undergo a workup to assess for mucosal abnormality and esophageal morphology and motility. Barium swallow is the best way to visualize a diverticulum and may also reveal a hiatal hernia, reflux, or motility impairment. Upper endoscopy enables intraluminal visualization of the esophagus and stomach to assess for malignancy, size, and location of the diverticulum and other mucosal abnormality such as esophagitis, ulcers, or Barrett esophagus. Localizing the diverticulum is important, as higher-level diverticula may require a transthoracic rather than a laparoscopic approach. Obtaining manometry is imperative to assess for underlying motility disorder; however, ambulatory 24-hour manometry may be required to diagnose or clarify the diagnosis in some patients.³ Although its use is uncommon, ambulatory manometry allows assessment of more than 1,000 swallows, during and between meals, awake and asleep, instead of the typical 10 swallows visualized with standard manometry. Endoscopic

or fluoroscopic guidance of the manometry probe may be required to prevent placement into the diverticulum.

OPERATIVE TECHNIQUE

The goal of surgery is to (1) relieve the functional outflow obstruction by performing a myotomy, (2) resect the diverticulum, and (3) recreate an antireflux barrier. The relative importance of each of these aspects may vary in an individual patient. Our typical approach is to perform a laparoscopic stapled resection of the diverticulum, a long myotomy across the gastroesophageal junction and onto the cardia of the stomach, and a partial fundoplication. The patient is positioned supine with split legs and both arms tucked in a setup similar to a Nissen fundoplication. Five ports are placed, with one 12-mm port and four 5-mm ports. Use of a 45° laparoscope is recommended. The surgeon stands between the patient's legs, and the assistant is on the left. The hepatogastric ligament is divided and dissection carried cephalad to divide the phrenoesophageal ligament, starting from the right crus and carrying over to the left, preserving the peritoneal covering of the crura. This dissection of the crura is carried out circumferentially until a Penrose drain can be placed around the esophagus, carefully preserving the vagus nerves. Next, the short gastric vessels are divided with an energy device in preparation for performing a partial fundoplication. The Penrose drain can then be used for traction to facilitate mediastinal dissection. If needed, endoscopic examination may be performed to define and locate the diverticulum. Once defined and completely dissected, a 60-French tapered bougie dilator is passed and diverticulectomy performed using an laparoscopic linear stapler with the stapler in line with the vertical axis of the esophagus. The muscle is closed over the staple line using a running suture. A myotomy is performed either anteriorly or opposite to the side of diverticulectomy. Longitudinal and circular fibers of the esophagus are divided for approximately 6 cm proximal to the esophagogastric junction and continued distally onto the gastric cardia for 2 cm. An endoscope is again used to ensure completeness of the myotomy, and an air test is performed to test for leak. The hiatus is then closed posteriorly with interrupted permanent suture, typically requiring one to two sutures. Finally, a partial fundoplication is performed, either a Dor (anterior) or Toupet (posterior). If a Dor fundoplication is chosen, the fundus is sutured to the muscular wall of the myotomy and right crus. If a Toupet fundoplication is chosen, the fundus is sutured to the left and right sides of the esophagus. We typically do not leave a drain or a nasogastric tube.

POSTOPERATIVE CARE

Patients are given nothing by mouth for one night after the procedure. A Gastrografin swallow is performed prior to

Table 55.1 Outcomes after minimally invasive surgery for epiphrenic diverticula

Authors	Series date	n	Surgical approach	Leak n (%)	Other morbidity	Mortality n (%)	Symptom outcome	Follow-up months
Del Genio ¹⁶	1994–2002	13	13 Lap D, M, Nissen-Rossetti	3 (23.1)	1 intraop mucosal tear 1 MI	1 (7.7)	100% symptom free	Mean 58
Fernando ¹⁷ 4 mid esophageal	1997–2002	20	10 Lap 7 VATS 2 Lap + VATS 1 Lap + L thoracotomy 12 D, M, partial F 4 VATS D, M 2 VATS D 2 Lap D, Collis–Nissen	4 (20.0)	1 intraop perforation 2 pneumonia 2 empyema 1 PE, 1 PTX 1 MI, 1 afib 1 CHF, 1 CVA 1 seizure 1 port site hernia 1 seroma 1 renal failure	0 (0)	72% excellent 11% good 6% fair 11% poor 2 recurrent diverticula 1 stricture required dilation	Median 15
Fraiji ¹⁸	1999–2001	6	6 Lap D, M, partial F	0 (0)	1 intraop perforation 1 pneumonia 1 empyema 1 prolonged ileus 1 empyema	0 (0)	100% excellent or good	Mean 9.3
Klaus ¹⁹	1996–2000	11	3 Lap Nissen 2 Lap M, partial F 1 Lap D 3 Lap D, M, partial F 1 Lap D, Nissen 1 Open thoracotomy D, M, partial F	1 (9.0)	1 empyema	0 (0)	1 died from esophageal cancer 2 mild heartburn 1 mild dysphagia	Mean 26.4
Matthews ²⁰	1997–2002	5	4 Lap D, M, partial F 1 VATS D, M	0 (0)	None	0 (0)	100% excellent	Mean 16.2
Melman ²¹	1999–2006	13	12 Lap D, M, partial F 1 Lap D, M	1 (7.7)	1 atelectasis requiring bronchoscopy	0 (0)	2 mild dysphagia 1 GERD NA	Mean 12.6
Myers ²²	1996–1997	3	2 Lap 1 Lap → Open 1 D, M, Dor 1 D, M, hiatal repair 1 D, M, gastrostomy	0 (0)	1 PTX	0 (0)	NA	NA
Neoral ²³	2002	3	3 Lap D, M, partial F	1 (33.3)	None	0 (0)	NA	NA (Continued)

Table 55.1 (Continued) Outcomes after minimally invasive surgery for epiphrenic diverticula

Authors	Series date	n	Surgical approach	Leak n (%)	Other morbidity	Mortality n (%)	Symptom outcome	Follow-up months
Palanivelu ²⁴	1994– 2006	5	2 Lap D 1 Lap D, F 2 Lap D, M, F	1 (20)	1 pneumonitis 1 dysphagia	0 (0)	1 recurrent diverticulum	NA
Rosati ²⁵	1994– 2009	20	18 Lap D, M, partial F 2 Lap D, M	1 (5.0)	None	0 (0)	1 died from squamous cell carcinoma 1 mild dysphagia 1 chest pain 1 heartburn	Median 52
Soares ²⁶	1997– 2008	23	19 Lap 2 VATS 3 open thoracotomy 21 D, M, partial F 1 D, M, Nissen 1, D, M, Roux-en-Y	1 (4.3)	2 pleural effusion 1 bleeding 1 port site hernia	1 (4.3)	Resolution of: Dysphagia 92.8% Regurgitation 78% Heartburn 78% Chest pain 57%	Median 45
Tedesco ¹⁰	1994– 2002	7	Lap D, M, partial F	1 (14.2)	1 acute paraesophageal hernia	0 (0)	85% excellent 15% good NA	Median 60
Van der Peet ²⁷	1993– 1999	5	4 VATS 1 VATS/lap 3 D 2 D + M	1 (20.0)	None	0 (0)	NA	NA
Zaninotto ²⁸	1993– 2005	22	5 open 17 Lap 14 D, M, partial F 3 D, partial F	4 (18)	22.7%	0	Improvement in symptom score 6 with dysphagia 4 received dilations	Median 53
Total		156		19 (12.2)		2 (1.3)		

Note: Afib, atrial fibrillation; CHF, congestive heart failure; CVA, cerebrovascular accident; D, diverticulectomy; F, fundoplication; GERD, gastroesophageal reflux disease; intraop, intraoperative; Lap, laparoscopic; M, myotomy; MI, myocardial infarction; PE, pulmonary embolism; PTX, pneumothorax; VATS, video-assisted thoracoscopic surgery.

starting oral feeds. If the swallow does not show evidence of a leak, patients are instructed to follow a full liquid diet for 2 weeks, prior to advancing to a regular diet.

COMPLICATIONS AND RESULTS

There are multiple small, heterogeneous case series that have examined outcomes after laparoscopic treatment of esophageal diverticula, as summarized in [Table 55.1](#). Examination of 156 patients from 14 separate case series revealed an operative mortality of 1.3% and a leak rate of 12.2%. Leak rates have been found to be higher if a myotomy is not performed.¹⁵ Leaks are either managed with drainage and/or stenting, or may require reoperation. The majority of authors report good or excellent long-term symptom control.

SUMMARY

A laparoscopic approach to surgical management of epiphrenic diverticula is safe and effective. Surgery must address the underlying etiology of the diverticula, with relief of outflow obstruction.

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Laparoscopic transhiatal esophagectomy for curative intent

MOSHIM KUKAR AND STEVEN N. HOCHWALD

INTRODUCTION

The first esophagectomy performed completely via laparoscopy through a transhiatal approach with a neck incision was in 1995 by DePaula et al.¹ Since then, minimally invasive transhiatal esophagectomy for the treatment of benign and malignant diseases of the esophagus has gained popularity in the last two decades.² Prospective studies comparing transhiatal with transthoracic esophagectomy for esophageal cancer have demonstrated equivalent long-term survival rates.^{3–5}

INDICATIONS

This procedure is best utilized for tumors of the distal third of the esophagus with or without long-segment Barrett esophagus. It can also be used in patients with type 1 or 2 gastroesophageal junction (GEJ) tumors, but in many of these patients an Ivor Lewis approach may be preferable. This technique is best reserved for patients who have no history of previous gastric surgery such as a Nissen fundoplication. The body mass index of the patient is relevant, as this approach, without the use of any chest incisions, is difficult in obese patients and in those patients with significant cardiomegaly. It is a favorable option for those patients with significant lung disease where chest incisions are to be avoided. It can be safely used in patients who have undergone neoadjuvant chemoradiation.⁶

SETUP AND PATIENT POSITIONING

The patient is instructed to take 6–8 oz of cream just before midnight the night before. In our and others' experience,

it helps to localize a thoracic duct leak.⁷ It is imperative to have an operating room bed that can go in steep reverse Trendelenburg position to facilitate dissection around GEJ and in the mediastinum. Long instruments, bariatric scopes, and reticulating energy devices are very helpful in our experience.

The patient is positioned supine with left arm tucked and neck tilted to the right. A shoulder roll is inserted to facilitate neck dissection ([Figure 56.1](#)). In addition to the A-line and Foley catheter, an 18F nasogastric tube (NGT) is inserted and confirmed to be in the appropriate location. The chest is prepped in addition to the abdomen and neck to allow for chest tube insertion, if indicated.

ABDOMINAL DISSECTION

In general, the operation can be routinely performed with the placement of four 5-mm incisions and one 12-mm incision. The camera should always be placed just to the left and above the umbilicus. Care is taken not to place any of the abdominal ports too far laterally, as this can interfere with mediastinal dissection. Entry into the abdomen is gained using a 5-mm Optiview trocar with a 0° laparoscope in the left upper quadrant just lateral to Palmer point. After confirming correct intraperitoneal placement, the abdomen is insufflated to a pressure of 15 mm Hg. The camera is switched to a 5 mm 30° scope. A thorough diagnostic laparoscopy is performed. Additional ports are placed, a 5 mm port, approximately 20 cm is placed below the xiphoid just to the left of midline and above the umbilicus. A 12-mm trocar is inserted at the same level of the camera port just to the right of the rectus abdominis muscle and another 5 mm in the right upper quadrant, superior and lateral to the 12-mm port. A 5-mm trocar is inserted in a subxiphoid location, slightly to the left



Figure 56.1 Patient positioning.

of midline. The track is dilated with a Hemostat clamp, and a Nathanson retractor is inserted to retract the left lobe of the liver anteriorly. The retractor is secured to the right side of the bed (**Figure 56.2**). The operating surgeon stands on the right side and utilizes the 12- and 5-mm as working ports. The assistant holds the camera and assists with the 5-mm port in the left upper quadrant.

The lesser omentum is incised, and dissection is carried up along the right crus of the diaphragm. A retrogastric tunnel is made, the left crus is identified, the loose areolar tissue is dissected bluntly, a grasper is passed from the

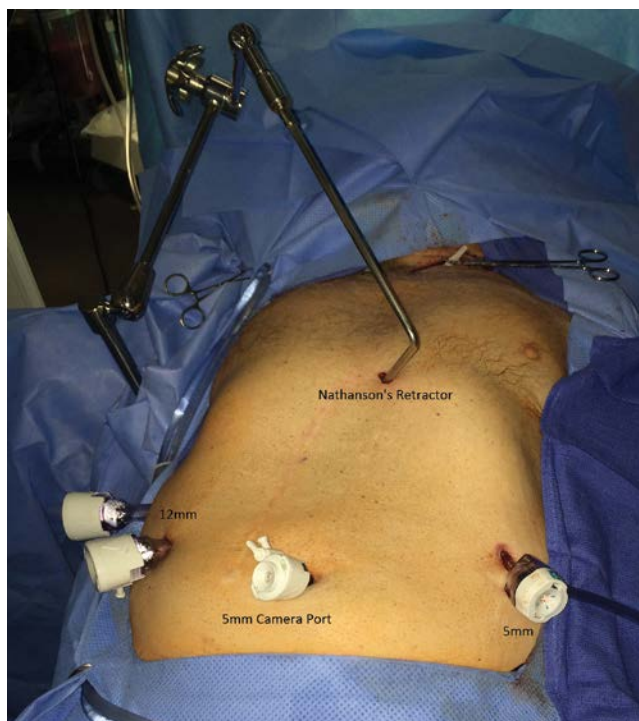


Figure 56.2 Abdominal port placement.

right side to the left just inferior to the pillars of the diaphragm, and the fundus is retracted down to visualize the tip of the grasper. Care should be taken to avoid injury to the spleen. A quarter-inch Penrose is encircled around the GEJ and secured with an Endoloop tie. Occasionally, with bulky tumors of GEJ, this may be difficult, and we mobilize the greater curve of the stomach prior to making the tunnel. Next, the anterior wall of the stomach is grasped and a window is made in gastocolic omentum to enter the lesser sac away from the right gastroepiploic arcade. After making an adequate window, the posterior wall of the stomach is grasped by the operating surgeon's left hand, which allows the right gastroepiploic arcade to flip anteriorly.

The dissection is continued along the greater curvature, dividing the left gastroepiploic and short gastric vessels all the way to the fundus until the left crus and the Penrose drain are visible using an articulating tissue sealer (ENSEAL G2, Ethicon). Most of this dissection is done from the right side except the most proximal short gastrics, which can be approached from the patient's left. The upper posterior dissection of the stomach is performed at this time with mobilization of the stomach away from the splenic artery and division of posterior gastric vessels if present. Gastropancreatic folds are divided, and further mobilization of the greater curvature toward the pylorus is performed by the assistant surgeon on the left side of the table. Transverse mesocolon is carefully mobilized off the right gastroepiploic arcade and the head of the pancreas. It is frequently helpful to identify the gastroduodenal artery early in the posterior dissection of the stomach. This allows for spatial orientation as to the location of the right gastroepiploic arcade.

A partial Kocher maneuver is performed to mobilize the duodenum so the pylorus can reach the GEJ with no tension. The right gastric artery arcade is isolated 4 cm proximal to the pylorus and divided with tissue sealer. The left gastric artery and vein are skeletonized to sweep the nodal tissue up along the specimen and divided using a vascular staple load. At this point the stomach is completely mobile, and all blood supply is divided except the right gastroepiploic vessels. We routinely check for pulsatile flow along the greater curve from these vessels, and if any doubt utilize a Doppler to confirm good blood flow before creation of the conduit. In over 300 minimally invasive esophagectomies, the gastroepiploic arcade has never been unintentionally damaged utilizing this approach coupled with meticulous dissection.⁸ Before creating the gastric conduit, it is important to reduce any hiatal hernia into the abdomen so that the entire stomach can be utilized for fashioning of the conduit. The gastric conduit is created using multiple firings of 3.5- or 4.8-mm, staple load, depending on the thickness of the stomach. We routinely use five to six staple loads, and care is taken to keep the width of the conduit around 5–6 cm. The conduit is fashioned so that the curve of the greater curvature is utilized to our advantage, resulting in a long conduit. The entire fundus of the stomach is utilized for the conduit,

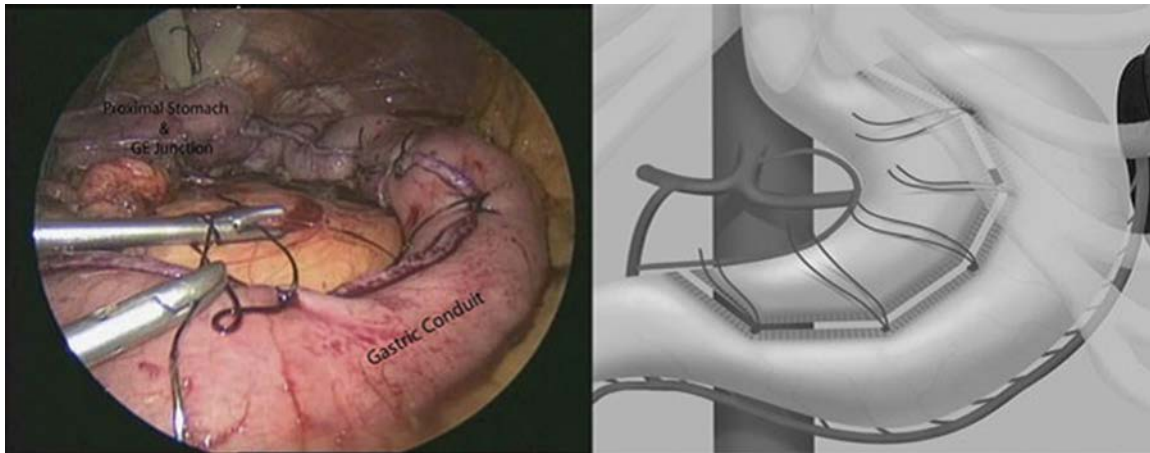


Figure 56.3 Creation of gastric conduit.

and attempts are made not to amputate across the fundus, resulting in a shorter conduit. A 2-0 silk EndoStitch is used to imbricate the intersecting staple lines, and the tails are left slightly longer to facilitate with orientation during the passage of conduit into the mediastinum (**Figure 56.3**). Ten milliliters of Botulinum toxin (100 units) are injected at two to three different areas in the anterior and posterior pylorus intramuscularly. We do not routinely perform a pyloroplasty.

MEDIASTINAL DISSECTION

It is preferable to perform the mediastinal mobilization of the esophagus after the gastric conduit has been completely fashioned and the stomach transected. This limits the chance of injury to the gastric conduit. Utilizing the Penrose as a handle, the GEJ is mobilized, taking care to dissect all paracardial lymph nodes and keep them with the specimen. The phrenoesophageal membrane is divided, and distal esophagus is further mobilized circumferentially. The nodes along the pericardium are included on the specimen. The vagus nerves are divided, and dissection is carried up to the carina. Long instruments, bariatric scope, and reticulating tissue-sealing device are very helpful at this stage and allow for good visualization and meticulous lymph node dissection. Care is taken to avoid entering the pleural spaces. Large lymphatics and aortic branches are clipped in addition to the vessel sealer. With appropriate retraction and assistance, dissection can be carried easily to the mid-esophagus before a neck incision is made (**Figure 56.4**).

CERVICAL DISSECTION

A 6-7-cm skin incision is made along the anterior border of the left sternocleidomastoid starting from the suprasternal notch. The platysma is divided. The sternocleidomastoid

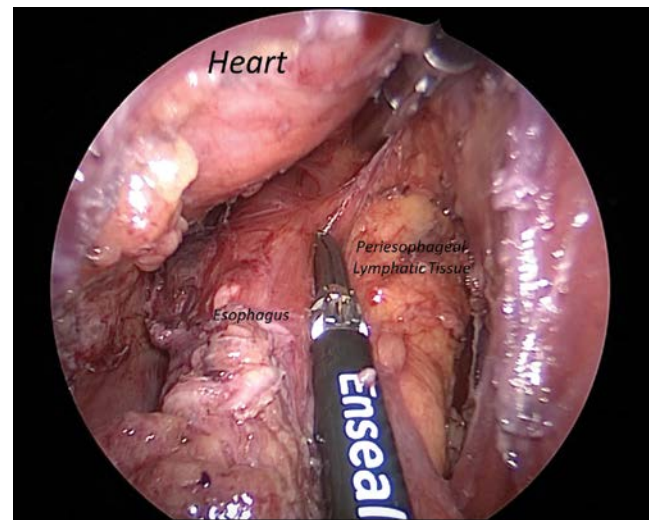


Figure 56.4 Transhiatal esophageal mobilization.

muscle is identified and moved laterally, carefully ligating and dividing any crossing jugular vein branches. A self-retaining retractor is used to facilitate further dissection. The inferior belly of omohyoid is divided, exposing the paravertebral fascia. Keeping the jugular vein and carotid artery laterally, the prevertebral fascia is opened, and the esophagus is identified. The esophagus is encircled taking care to avoid injury to the recurrent laryngeal nerve (**Figure 56.5**). A Penrose is placed around the esophagus, and with firm retraction, the cervical esophagus is mobilized with blunt finger dissection. It is helpful to mobilize the cervical esophagus and then return to the abdomen and continue the mediastinal esophageal mobilization. Following this, a blunt long curved Kelly or Rochester clamp is inserted through the cervical incision and gently advanced through any remaining posterior mediastinal attachments of the esophagus. Subsequently, this same maneuver is performed with the clamp anterior to the esophagus. The clamp is



Figure 56.5 Mobilization and encircling the cervical esophagus.

utilized to spread apart remaining attachments of the esophagus to the mediastinum. With the esophagus more mobile, the remaining lateral attachments are mobilized and divided utilizing the abdominal ports under direct vision. Blood loss should be minimal with this approach. After complete mobilization of the entire thoracic and lower cervical portions of the esophagus, the tip of the gastric conduit is anchored to the specimen with two silk sutures. Occasionally, it may be necessary to deliver the specimen out of the neck incision before pulling up the gastric conduit. In this situation, a chest tube can be easily advanced via the neck incision, through the mediastinum and the diaphragmatic hiatus. The gastric conduit can then be sutured to the chest tube and pulled out of the cervical incision for the anastomosis.

RECONSTRUCTION

The conduit is delivered through the mediastinum and up to the neck with care taken to preserve the proper orientation. The anastomosis is performed as previously described.^{9,10} The sutures holding the specimen to the conduit are cut. The cervical esophagus and the conduit are aligned so that an anastomosis can be created between the posterior wall of the stomach and anteromedial aspect of the esophagus. Judicious care is taken to ensure the correct orientation of the conduit at all times. An esophagotomy is made, and the tip of the nasogastric tube is pulled out through this hole. A gastrostomy is made on the posterior wall of the stomach 2–3 cm distal to the tip of the conduit in an area of healthy looking stomach. Using a 60, 3.5-mm load on the Endo GIA, a 6-cm side-to-side stapled anastomosis is created (**Figure 56.6**). The stapler is introduced and fired in a proximal to distal manner on the stomach and in a distal to proximal manner on the esophagus. Care is taken to avoid catching the nasogastric tube in the stapler. After firing the linear stapler, the nasogastric tube is advanced through the anastomosis, and the tip is left in the lower aspect of the conduit. The common esophagogastric channel is closed with a 60, 3.5-mm load of TA stapler with excision of the tip of the conduit. The specimen consisting of the esophagus and upper stomach is transected. At the same time, the apex of the gastric conduit is transected. All specimens are sent to pathology. After firing the TA stapler, it is left in place and serves as a handle to allow the placement of two 3–0 silk sutures at the crotch of the staple line to decrease any tension. The gastroesophageal staple line is imbricated with a running 3–0 PDS suture. The anastomosis is carefully pushed back into the posterior-superior mediastinum. A 7F Jackson Pratt is placed along the anastomosis. The platysma is approximated with interrupted 3–0 Vicryl sutures, and the skin is closed with 4–0 Monocryl. Intra-abdominally, the conduit is gently pulled down into the abdomen to ensure that there is no

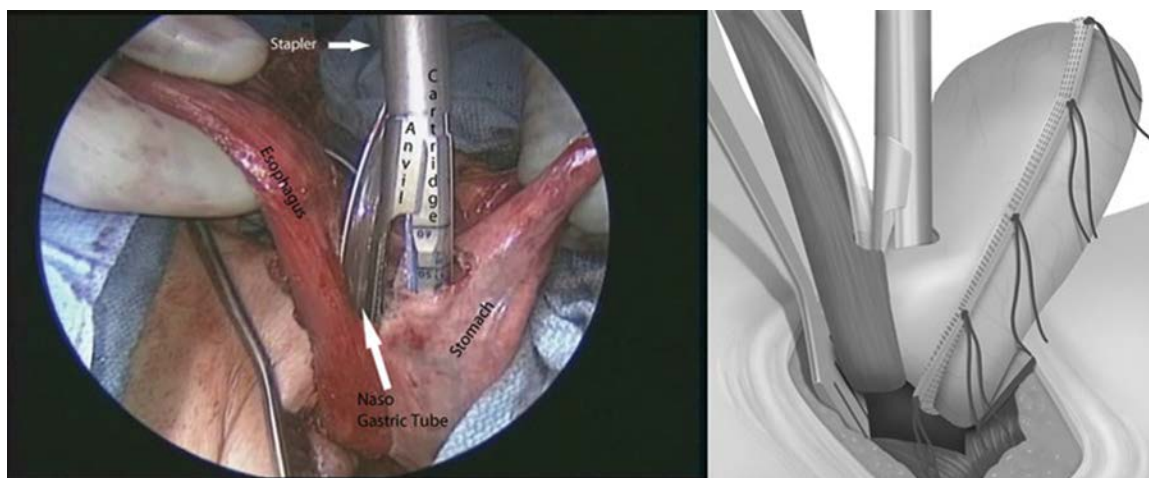


Figure 56.6 Side-to-side stapled esophagogastrostomy.

redundant conduit in the mediastinum. The conduit is then sutured to the left crus of the diaphragm with two 2–0 silk sutures to avoid herniation of intra-abdominal contents into the mediastinum.

A prefashioned 16 F T tube (back wall is cut and a portion is removed) is inserted in the proximal jejunum 15–20 cm from the ligament of Treitz as previously described.^{11,12} It is anchored to the abdominal wall with multiple transfacial sutures. The single 12-mm port is closed with 0 Vicryl using a Carter Thomason device. All incisions are closed with 4–0 Monocryl and Dermabond is applied.

POSTOPERATIVE CARE

We follow an esophagectomy pathway at our institution.¹³ Postoperative pain is usually not significant due to utilization of laparoscopic incisions together with a limited neck incision.

- Patients are transferred to a monitored setting for overnight observation and transferred to the floor on postoperative day 1 with telemetry monitoring.
- Day 2, they are started on trickle tube feeds, and the Foley catheter is discontinued.
- Day 3, NGT is removed if chest x-ray shows a decompressed conduit.
- Day 4, they are given a trial of colored clears and neck JP is removed.
- Day 5, they are advanced to full liquids.
- Day 6–7, patients are advanced to 50% of the caloric needs by tube feeds when they have full return of gastrointestinal function. They are usually discharged on postoperative day 7, receiving 50% of their calories through the feeding tube and simultaneously eating a full liquid diet for 2 weeks.

Several series of patients undergoing laparoscopic transhiatal esophagectomy exist in the literature.^{14–17} The number of surgical cases in these five studies is limited and ranges from 9 to 22. Avital et al.¹⁴ reported their outcomes in 22 patients who underwent laparoscopic transhiatal esophagectomy. The conversion rate was 4.5%. The

average operative time was 380 minutes (range 285–525 minutes). The median hospital stay was 8 days, and 30-day mortality and morbidity was 4.5% and 27.2%, respectively (one patient had an anastomotic leak). Median follow-up was 30 months with overall survival of 61% and disease-specific survival of 39%. The short-term outcome data in this study and other smaller studies compare favorably with open esophagectomy; however, long-term oncologic data are missing in most studies. Whether this technique should be utilized in all patients is controversial, due to a limited ability to perform a mediastinal node dissection. However, it is a good tool to have in the armamentarium of a minimally invasive esophageal surgeon and can be selectively utilized with excellent short-term functional and oncologic outcomes.

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Minimally invasive Ivor Lewis method for resection of esophageal cancer

JOHN-PAUL BELLISTRI AND W. SCOTT MELVIN

INTRODUCTION

Esophageal cancer, including cancer of the gastroesophageal junction (GEJ), is a worldwide health issue. The number of new cases in the United States in 2014 was estimated to be approximately 18,170 with a prevalence of 4.4 per 100,000 men and women.¹ The 5-year survival rate of esophageal cancer is 17.5% from 2004 to 2010, with the overwhelming majority of survivors having undergone surgical resection.¹ The two major histologic subtypes of esophageal cancer are squamous cell carcinoma (SCC) and adenocarcinoma (AC). Each subtype has a different geographical prevalence. The prevalence of AC has been on the rise in the United States and is the most common histologic subtype found in the United States and Western Europe.^{2,3} Conversely, SCC is the most common histologic subtype in Asia and Eastern Europe.^{2,3} In addition, most esophageal cancers diagnosed in Western countries are located in the lower esophagus or GEJ.^{2,3}

Surgery provides the best chance of cure for esophageal cancer. In very early stage disease, endoscopic intervention has evolved as an option. However, only surgical resection allows for the removal of the primary tumor as well as draining lymph node stations. This chapter describes a minimally invasive combined transabdominal and transthoracic approach to resection of esophageal cancer.

BACKGROUND

The esophagus is a difficult surgical field for three reasons: its inaccessibility; its lack of a serous coat; and its enclosure in structure where infection is especially dangerous and rapid.

In 1946, Ivor Lewis used these words to open his seminal paper to describe some of obstacles toward successful

operations on the esophagus. Lewis, along with contemporaries Garlock and Sweet, was the first to perform esophagectomy via a transpleural approach with any semblance of success. At that time, the procedure was carried out in two stages, transabdominal and transthoracic, separated by 10–15 days. The procedure at that time carried an approximate 30% risk of on-table mortality.⁴

Over the last 70 years, the Ivor Lewis esophagectomy has evolved as a safe surgical approach while adhering to principles of sound oncologic resection. Nguyen and colleagues were some of the first to show that minimally invasive esophageal resection, when compared with open approaches, carries a decrease in operative times, blood loss, blood transfusions, intensive care unit stay, and hospital courses. This was accomplished without compromising integrity of the anastomosis or increasing pulmonary complications.⁵ Since that time, multiple studies have demonstrated decreases in morbidity, postoperative pain, and reconfirmed decreases in hospital stay.⁶ In terms of oncologic outcomes, the minimally invasive approach to esophageal resection has been shown to provide equal if not improved ability to accomplish complete resection (R0) and adequate lymph node dissection.⁶ With increasing experience of surgeons in the realm of minimally invasive surgery, the minimally invasive Ivor Lewis esophagectomy has now become the optimal surgical approach to malignancy involving the middle and distal aspects of the esophagus as well as malignancy of the GEJ.

PREOPERATIVE PLANNING

Oncologic workup and staging

Patients found to have esophageal cancer need to undergo a series of preoperative investigations in order to fully

Table 57.1 Preoperative oncologic workup

- History and physical examination
- Upper gastrointestinal endoscopy with biopsy
- Chest/abdominal CT with oral and intravenous contrast
- PET-CT evaluation if no evidence of M1 disease
- Complete blood count and comprehensive chemistry profile
- Endoscopic ultrasound if no evidence of metastatic disease
- Bronchoscopy if tumor is at or above the carina without evidence of metastatic disease
- Biopsy and HER2 testing if metastatic disease
- Assign Siewart category
- Nutritional assessment and counseling
- Smoking cessation advice, counseling, and pharmacotherapy
- Screen for family history

Source: www.NCCN.org.

characterize extent of disease and determine resectability. Oncologic workup begins with a thorough history and physical examination. Diagnosis is obtained by upper gastrointestinal endoscopy with biopsy. Complete blood count, chemistry profile, and liver function tests are indicated. Computed tomography (CT) of the chest and abdomen with oral and intravenous contrast provides images to assess the extent of disease. In order to identify possible metastatic disease, positron emission tomography (PET)-CT is indicated. In the absence of metastatic disease, endoscopic ultrasound (EUS) is indicated in order to assess depth of invasion of primary tumor and to quantify and characterize lymph node involvement. Bronchoscopy is indicated for tumors extending above the level of the carina in order to assess for possible tracheal involvement. Nutritional status and smoking cessation are also important aspects of preoperative preparation⁷ (**Table 57.1**).

The tumor (T), node (N), and metastasis (M) method of classification system has been utilized for the staging of esophageal cancer since 2002, and **Table 57.2** includes the most up-to-date staging system.⁸ T1a (intramucosal) lesions may be amenable to endoscopic mucosal resection, although there is a paucity of long-term data. T1b tumors (submucosal invasion) are not amenable to endoscopic resection due to the lymphatic channels that course at this level. Therefore, appropriate lymphadenectomy is indicated for such tumors, which can only be accomplished surgically. Contraindications to curative resection include M1 disease, T4b tumors (invasion of any adjacent structure other than pleura, pericardium, or diaphragm), or lesions of the cervical esophagus (within 5 cm of the cricopharynx). Those patients with tumors of the cervical esophagus should undergo definitive chemoradiation. In addition, patients with level 1 (low cervical, supraclavicular, and sternal notch), level 18 (common hepatic), or level 19 (splenic) lymph node involvement would not be considered for curative resection, as these are not considered regional lymph node stations.⁷

Laparoscopic staging

Laparoscopic staging, when considered, includes diagnostic laparoscopy, peritoneal washings, gastric ischemic conditioning, and creation of feeding access. This can be performed anywhere from 2 days to 3 months prior to definitive surgical resection depending on whether the patient will be receiving neoadjuvant therapy. At times, creation of feeding access is performed in the same setting as definitive resection. Diagnostic laparoscopy with peritoneal washings should be considered for T3 tumors, tumors with nodal involvement, and Siewart II or III (**Table 57.3**). This aids in identifying patients with Stage IV tumors, and therefore, those for whom curative surgical resection would not be possible.^{9,10} Gastric ischemic conditioning involves ligating the left gastric vessels, which increases submucosal collateral flow and mucosal oxygen saturation. However, there are no clinical studies that show a decrease in rates of anastomotic leak or dehiscence when gastric ischemic conditioning is performed.^{11,12} Jejunostomy is created in the proximal jejunum in order to accommodate postoperative alimentation while protecting the esophagogastric anastomosis.

SURGICAL TECHNIQUE

Patient setup

Minimally invasive Ivor Lewis esophagectomy is performed in two stages. The first stage is performed laparoscopically with the patient in supine position. The second stage is performed thoracoscopically with the patient in a left lateral decubitus position. Upon placement of the patient on the operating room table, bilateral sequential compression devices are placed on both legs. Heparin is administered subcutaneously prior to induction of anesthesia. Upon induction of general anesthesia, a dual lumen endotracheal tube is utilized for a left mainstem intubation. A Foley catheter is also placed for the monitoring of urine output. Preoperative antibiotics are administered. An arterial line is placed for hemodynamic monitoring throughout the duration of the procedure.

First stage: Laparoscopic stage

The first stage of the operation is the abdominal portion. This is performed with the patient in supine position. The surgeon is situated to the right of the patient with the assistant to the left of the patient. Upon entrance into the abdomen pneumoperitoneum is achieved to a pressure of 15 mm Hg. Five trocars are used for the abdominal portion of the surgery. A 10-mm port is placed at the left midclavicular line to accommodate a 10-mm 30° camera scope. Another 5-mm port is placed at the left anterior axillary line just below the costal margin. This port allows for instrumentation to be

Table 57.2 American Joint Committee on Cancer (AJCC) TNM classification of carcinoma of the esophagus and esophagogastric junction (7th ed. 2010)**A. TNM Classification and Histologic Grade****Primary Tumor (T)**

TX—Primary tumor cannot be assessed

T0—No evidence of primary tumor

Tis—High-grade dysplasia (HGD)

T1—Tumor invades lamina propria, muscularis mucosae, or submucosa

T1a—Tumor invades lamina propria or muscularis mucosae

T1b—Tumor invades submucosa

T2—Tumor invades muscularis propria

T3—Tumor invades adventitia

T4—Tumor invades adjacent structures

T4a—Resectable tumor invading pleura, pericardium, or diaphragm

T4b—Unresectable tumor invading other adjacent structures, such as aorta, vertebral body, trachea, etc.

Regional Lymph Nodes (N)

NX—Regional lymph nodes cannot be assessed

N0—No regional lymph nodes

N1—Metastasis in one to two regional lymph nodes

N2—Metastasis in three to six regional lymph nodes

N3—Metastasis in seven or more regional lymph nodes

Distant Metastasis (M)

M0—No distant metastasis

M1—Distant metastasis

Histologic Grade (G)

GX—Grade cannot be assessed (stage grouping as G1)

G1—Well differentiated

G2—Moderately differentiated

G3—Poorly differentiated

G4—Undifferentiated (stage groupings as G3 squamous)

B. Anatomic Stage/Prognostic Groups**Squamous Cell Carcinoma**

Stage	T	N	M	G	Tumor location (proximal extent of tumor)
Stage 0	Tis (HGD)	N0	M0	1,X	Any
Stage 1A	T1	N0	M0	1,X	Any
Stage 1B	T1	N0	M0	2,3	Any
	T2–3	N0	M0	1,X	Lower
Stage IIA	T2–3	N0	M0	1,X	
	T2–3	N0	M0	2–3	
Stage IIB	T2–3	N0	M0	2–3	Upper, middle
	T1–2	N1	M0	Any	Any
Stage IIIA	T1–2	N2	M0	Any	Any
	T3	N1	M0	Any	Any
	T4a	N0	M0	Any	Any
Stage IIIB	T3	N2	M0	Any	Any
Stage IIIC	T4a	N1–2	M0	Any	Any

(Continued)

Table 57.2 (Continued) American Joint Committee on Cancer (AJCC) TNM classification of carcinoma of the esophagus and esophagogastric junction (7th ed. 2010)

	T4b	Any	M0	Any	Any
	Any	N3	M0	Any	Any
Stage IV	Any	Any	M1	Any	Any
Adenocarcinoma					
Stage	T	N	M	G	Tumor location (N/A)
Stage 0	Tis (HGD)	N0	M0	1, X	
Stage 1A	T1	N0	M0	1–2, X	
Stage 1B	T1	N0	M0	3	
	T2	N0	M0	1–2, X	
Stage IIA	T2	N0	M0	3	
Stage IIB	T3	N0	M0	Any	
	T1–2	N1	M0	Any	
Stage IIIA	T1–2	N2	M0	Any	
	T3	N1	M0	Any	
	T4a	N0	M0	Any	
Stage IIIB	T3	N2	M0	Any	
Stage IIIC	T4a	N1–2	M0	Any	
	T4b	Any	M0	Any	
	Any	N3	M0	Any	
Stage IV	Any	Any	M1	Any	

utilized by the assistant. A 12-mm port is then inserted at the right of the midline superior to the level of the umbilicus to accommodate instruments and linear cutting staple devices. Another 5-mm port is placed at the right midclavicular line. A 5-mm port is then placed at the left anterior axillary line to accommodate a liver retractor.

The patient is then placed in reverse Trendelenburg position, and the dissection begins at the gastrohepatic ligament. The pars flaccida is taken followed by the pars densa to the esophageal hiatus. The hiatus is not dissected at this time. The left gastric artery is taken at the origin of the celiac. This is accomplished with a linear cutting stapler with 2.0-mm staples. Taking the left gastric artery at its origin allows for *en bloc* resection of the left gastric lymph nodes with the specimen. Attention is then directed to the greater curvature of the stomach, and the greater omentum is taken approximately 3 cm from the stomach so as to preserve the right gastropiploic artery. The short gastric vessels are then taken to free the greater curvature of the stomach to the angle of His.

Table 57.3 Siewert classification

- Siewert Type I—Adenocarcinoma of the lower esophagus within 1–5 cm from esophagogastric junction (EGJ)
- Siewert Type II—Carcinoma of the cardia within 1 cm above and 2 cm below EGJ
- Siewert Type III—Subcardial carcinoma within 2–5 cm below EGJ

Note: Types I and II should be approached in a similar fashion to other esophageal tumors; Type III should be approached as a gastric tumor.

A Heineke-Mikulicz pyloroplasty can be performed by creating a full-thickness, longitudinal incision through the pylorus. A 2–0 nonabsorbable suture material is used to close the defect in a single-layer transverse fashion. The gastric conduit is then constructed beginning at the lesser curvature. Linear cutting staplers are used for this portion of the procedure. The cardia is separated from the body and fundus so as to accommodate at least a 2-cm distal margin while creating a gastric conduit with a 4–5-cm diameter. The staple line is then imbricated with 2–0 nonabsorbable suture material. The conduit is then sutured to the specimen in order to ensure alignment of the conduit and facilitate translocation into the thoracic cavity during the second stage of the operation.

The phrenoesophageal ligament is divided, and the esophagus is dissected circumferentially approximately 5–6 cm into the thoracic cavity. A 1-inch Penrose is then placed around the esophagus and sutured together. The tails of the Penrose are placed into the thoracic cavity to facilitate pull-up of the specimen and conduit. A Witzel-type feeding jejunostomy is then created using standard techniques if one was not previously in place. The abdomen is then desufflated in preparation for the thoracoscopic portion of the operation.

Second stage: Thoracoscopic stage

The patient is then placed in the left lateral decubitus position for the thoracoscopic portion of the operation. For this portion of the surgery, the operating surgeon stands to the back of the patient with the assistant opposite to him or her. Once repositioned, the appropriate location of the dual lumen endotracheal tube is reconfirmed by bronchoscopy. Single-lung ventilation is then initiated in order to decompress the right lung. A suction catheter can be placed into the right mainstem bronchus to help decompress the right lung.

Four trocars are utilized. The chest is entered at the eighth intercostal space midaxillary line to accommodate a 10-mm port. A 10-mm 30° camera is then inserted into this port to be controlled by the assistant. The working port for the operating surgeon is placed at the ninth intercostal space posterior axillary line. An approximately 4-cm incision is made at this level. A wound protector is placed over the incision, and a 10-mm trocar is inserted. This will serve as the specimen extraction site. A 5-mm trocar is then inserted at the fourth intercostal space just posterior to the scapula. Another 5-mm assistant port is then inserted at the sixth intercostal space anterior axillary line to be utilized by the assistant.

The lower lobe of the right lung is retracted toward the anterolateral chest wall. The inferior pulmonary ligament is then taken with a thermal device to expose the esophagus. The previously placed Penrose is then accessed through the esophageal hiatus and used to retract the esophagus through the hiatus. The esophagus is then mobilized to the level of the azygous vein. In doing so, care is taken to include parasophageal and subcarinal lymph node stations. When dissecting the posterior aspect of the esophagus, care is taken

to ligate aortoesophageal arterial branches and branches of the lymphatic tributaries to the thoracic duct. The azygous vein is then dissected and divided with a linear cutting stapler. Dissection of the esophagus is then continued approximately 2 cm cranial relative to the azygous.

Once the esophagus has been fully mobilized, the Penrose is utilized to translocate the distal specimen and gastric conduit into the thoracic cavity. The previously placed sutures joining the specimen to the conduit are removed, and the proximal esophagus is transected with endoscopic scissors. The specimen is then removed from the thoracic cavity through the surgeon's working port with the wound protector in place. The specimen is sent for frozen histopathology analysis to ensure adequate margins.

Creation of the esophagogastrostomy is accomplished using a circular stapling device with a 25-mm diameter, if possible. The anvil is inserted into the proximal esophagus, which is then secured in place using a 2–0 nonabsorbable suture in a pursestring fashion.

The conduit is then oriented appropriately with the lesser curvature staple line facing the lateral chest wall. A gastrotomy is created at the tip of the staple line in order to accommodate the endoscopic circular stapling device. The circular stapler is lubricated and then inserted into the working port and passed through the gastrotomy. The pin is then brought out through the greater curvature of the stomach. The anvil is docked on the pin, brought into the stapling device, and the stapler is fired creating an end-to-side esophagogastrostomy (end of esophagus to side of gastric conduit). The previously made gastrotomy is then excised with a linear cutting stapler with 3.5-mm staple loads.

The thoracic cavity is then thoroughly irrigated. A nasogastric tube is passed through the anastomosis to the level of the middle of the conduit. A #10 Jackson-Pratt drain is left posterior to the conduit as it enters into the thoracic cavity. A 28Fr chest tube is inserted through the camera port and placed posteriorly to the apex. The patient is placed back in supine position for extubation.

POSTOPERATIVE MANAGEMENT

The patient is transferred to the intensive care unit postoperatively. A nasogastric tube is placed to low-intermittent wall suction. A chest tube is placed to pleurovac suction at 20 cm H₂O. The patient receives patient-controlled analgesia. Aggressive pulmonary toilet is essential ensuring the patient can elicit a good cough and can use the incentive spirometer. Jejunal feeding is commenced on the first postoperative day. An upper gastrointestinal series can be obtained on postoperative day 4 with Gastrografin to assess for anastomotic leak. If there is no leak, then the nasogastric tube can be removed. The chest tube can also be removed at this time as long as output is at a minimum (<200 mL per day). Upon discharge, the patient returns to clinic after 2 weeks. The jejunostomy is maintained until the patient is able to take sufficient nutrition by mouth.

COMPLICATIONS

Esophagectomy in general can carry a mortality rate from 8% to 23% depending on the surgeon and center in which it is performed.¹³ The incidence of mortality after minimally invasive esophagectomy can be as low as <1% in high-volume centers.¹³ Anastomotic leak is among the most dreaded of complications and occurred in 4%–15% of cases.¹⁴ Small leaks that are asymptomatic and contained with good drainage into the Jackson-Pratt drain can be treated conservatively with continued drainage, antibiotics, and monitoring. Other complications include cardiac arrhythmia, myocardial infarction, heart failure, respiratory failure, pneumonia, atelectasis, deep vein thrombosis, pulmonary embolism, and vocal cord paralysis.¹⁴

RESULTS

When minimally invasive approaches are compared with open procedures, operative times, blood loss, transfusion requirements, and intensive care unit stay are reduced.⁵ Few studies have gained the statistical power to compare minimally invasive Ivor Lewis esophagectomy with other approaches to esophageal resection.¹⁴ However, multiple meta-analyses have exhibited favorable outcomes in regard to perioperative morbidity and postoperative pain as well as length of stay when minimally invasive approaches are compared with open approaches.^{15–17}

The Eastern Cooperative Oncology E2202 Study was a prospective multicenter study that examined outcomes of minimally invasive esophagectomy by surgeons who have performed at least five minimally invasive esophagectomies, eight esophageal resections per year, and 10 minimally invasive esophageal cases per year. There were 17 sites involved in the study. Analysis was performed on 95 patients who had undergone minimally invasive esophagectomy (McKeown or Ivor Lewis) with 30-day mortality as the primary endpoint, and adverse events, length of stay, and 3-year outcome as secondary endpoints. This study showed a mortality of 2.1% and 3-year survival of 58.4%. Overall, this study showed that surgeons with appropriate expertise in minimally invasive surgery and open esophageal resections can perform minimally invasive esophageal resections with favorable outcomes.¹³

Minimally invasive Ivor Lewis esophagectomy has also been compared with minimally invasive McKeown

esophagectomy. In a study where 530 patients underwent Ivor Lewis esophagectomy and 481 patients underwent McKeown esophagectomy, Ivor Lewis esophagectomy was associated with a reduction in overall mortality (0.9% versus 2.5%) and a lower incidence of recurrent laryngeal nerve injury in the Ivor Lewis groups compared with the McKeown group.¹⁸

CONCLUSIONS

Minimally invasive Ivor Lewis esophagectomy is a safe and effective approach toward resection of esophageal cancer. A minimally invasive approach avoids the morbidity associated with open thoracotomy and laparotomy incisions, while maintaining adherence to principles of oncologic resection with improved outcomes.

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Minimally invasive treatment of gastric disease



Tim Hawkinson, *Überorgan*, 2000. Woven polyethylene, nylon net, cardboard tubing, various mechanical components; dimensions variable. Installation view, 590 Madison Avenue, New York, NY, February 11–May 2, 2005. Organized by the Whitney Museum of American Art and Los Angeles County Museum of Art. (Photography by G. R. Christmas, © Tim Hawkinson, courtesy Pace Gallery.)

Sculptor Tim Hawkinson is known for making extraordinary pieces from very ordinary materials. He was initially prompted to make this monumental work, named *Überorgan*, for a former factory-turned-museum called MASS MoCA, in North Adams, MA, in 2000. This challenged the artist to think about how he might fill a space the size of a football field while also creating an auditory experience. Resembling human organs, these massive inflatable balloons were fabricated from several miles of plastic sheets

stitched together with everyday electrical wire. The “thin membranes filled with air,” as the artist calls them, are connected on one end to a light-sensitive keyboard and on the other to protracted foil-encased horns by snaking, intestine-like tubes. The result is a massive bagpipe that at regular intervals plays a tune composed by the artist from a long, translucent scroll speckled with musical notes. The hymn, based on a scale of twelve tones, resembles a low horn or a whale call, or even an exaggerated bowel sound.

Hawkinson often uses imagery of the human body in his work to explore our experience in our bodies and their relationship with the outside world. However, here he has defied our expectations by playing with their scale: where normally organs are small and intimate, he has monumentalized them, making them large, loud, and intrusive. The intimacy of its fabrication by hand in the studio, much like a surgery, is betrayed by its humongous size. Seen here, installed in the atrium of the IBM building on Madison Avenue in New York, it is as if the interior workings of the operating

room are exposed above the very heads of the people sitting below enjoying a coffee. Since the early 2000s, the work has been reconfigured in a number of spaces—in an art gallery, this office building, and later at the J. Paul Getty Museum in Los Angeles. At each location, the work takes on a new life.

Quotes from “‘Überorgan,’ Tim Hawkinson,” Art21, published September 2003, <https://art21.org/read/tim-hawkinson-uberorgan/>.

Peptic ulcer disease

HENRY LIN*

HISTORY OF PEPTIC ULCER DISEASE

Since the 1950s, the incidence of peptic ulcer disease (PUD) and its complications continues to decrease,¹⁷ down to 1 in 10 Americans.¹⁰ The cause of PUD has shifted in paradigm from Schwartz's "no acid, no ulcer" to Graham's "no *Helicobacter pylori*, no ulcer"⁷ and a few other etiologies.^{5,9}

Helicobacter pylori is present in 80%–100% of duodenal ulcers.¹⁵ In the remaining *H. pylori*-negative patients, 50%–60% of those ulcers are caused by nonsteroidal anti-inflammatory drugs (NSAIDs) or aspirin (ASA).¹ Smoking contributes to perforated and refractory PUD.¹⁵ Other etiologies include steroids and possibly alcohol. Crack cocaine can result in perforated PUD in rare cases.¹⁹

Surgery for PUD is currently reserved for complications in selected patients, including perforation, bleeding, obstruction, and exceedingly rare intractability.

In fact, there are many who feel that operating for PUD in nonemergent cases is no longer recommended.¹³

Perforation prevalence in PUD is only 2%–10%.³ In episodes of upper gastrointestinal (UGI) bleeding, PUD is responsible for 28%–59% of cases and has a 10% mortality rate. In 15%–25% of patients with bleeding ulcers, the bleeding cannot be primarily controlled through endoscopic means and may require alternative treatment like angio-embolization in critically ill patients.

PUD accounts for less than 9% of those patients with gastric outlet obstruction.¹⁰ In the past decade, referrals to surgeons for surgical treatment were expected to be less than 10% of all patients with chronic PUD.¹⁴

Presumptively from the widespread use of H₂-blockers, proton pump inhibitors, eradication therapy for *H. pylori*, and the use of sucralfate, the incidence of surgery for peptic ulcer disease and its complications has overall decreased in the twenty-first century. Hospitalizations for PUD

decreased in the United States from 1993 to 2006, suggesting a decrease in the prevalence and/or severity of ulcer complications over this recent time period.¹⁸

In the past two decades, surgical oversewing has not changed (approximately 7% of hospitalizations for PUD), but the frequency of gastrectomy has dropped by 50% (4.4%–2.1%) and of vagotomy by 70% (5.7%–1.7%). Total admissions for PUD dropped from more than 222,000 in 1993 to 156,000 in 2006 in the United States.¹⁸ At a tertiary center, these operations occur less than 15 times per year.^{7,8,16}

There is very little consensus on guidelines for management,⁴ and there currently appears to be three approaches, although the first approach appears to have the most support:

1. Vagotomy is rarely needed in the era of medical control of acid secretion and treatment of *H. pylori*.^{11,13}
2. Laparoscopic posterior vagotomy and anterior seromyotomy or linear gastrectomy achieve the equivalent physiologic effect of highly selective vagotomy.
3. The laparoscopic approach to highly selective vagotomy can be safe in the appropriate hands, with care to avoid lesser curvature devascularization.

The laparoscopic approach to PUD complications in selected patients suggests improved postoperative hospital course, including 1.2 days shorter hospital stay, less intravenous or intramuscular opiate analgesia, less intravenous fluid requirement, earlier return to normal diet, earlier patient mobility, and shorter duration for the utilization of a nasogastric tube, urinary catheter, and abdominal drain.² Hence, if the surgical expertise is available, the laparoscopic approach may be superior, but further studies are required for full validation.¹²

PATIENT SELECTION

Perforation of PUD almost always requires operative treatment. Nonoperative expectant management, however, may

* With illustrations by Gary Wind.

be considered in select cases of contained perforations or in patients under age 70.¹ The current operation of choice is suture closure with a Graham patch and follow-up medical treatment, usually for *H. pylori*.

Indications for surgical treatment of bleeding duodenal ulcer include the following⁹:

1. Failure of endoscopic treatments (especially after two attempts)
2. Failure of angioembolization
3. Transfusion of more than three units of packed red blood cells in less than 24 hours or without cessation of bleeding
4. Concomitant “giant gastric ulcer” (>3 cm) due to 30% incidence of malignancy
5. Twelve weeks of persistent bleeding despite medical treatment

The operations for bleeding PUD are usually not performed laparoscopically, since the pneumoperitoneum may be difficult to maintain with significant intraoperative suction. Also, the pneumoperitoneum decreases venous return to the heart and worsens hemodynamic instability for those bleeding patients.

Evaluation for gastrinoma should be performed in ulcers in the third and fourth portions of the duodenum and for intractability. Giant (>3 cm) gastric ulcers need to be biopsied to exclude malignancy.

Elective laparoscopic management of PUD is advocated rarely but for the following reasons:

1. Disease resistant to medical treatment for >2 years with documented recurrences
2. Patients unable to be followed regularly due to geographic or socioeconomic reasons or who cannot afford long-term medication
3. Helicobacter [pylori] negative and off other inciting agents (NSAIDs, aspirin, steroids, smoking).⁷

The decision to operate laparoscopically versus using the open technique depends on the individual surgeon's skill,¹² whether the ulcer is causing significant bleeding, and the patient's condition. Relative contraindications to the laparoscopic approach include the following:

1. Greater than 1.5- to 2-cm perforation, which may prevent technically feasible closure without a Graham patch
2. Preexisting gastric outlet obstruction (unless the skill set for laparoscopic gastrojejunostomy exists with the surgeon)

Although the laparoscopic technique does have a higher reoperative rate, the hospital course appears to be less complex.²

In these occasional elective cases, the general medical status should be optimized and the anesthetic risk minimized preoperatively.

INSTRUMENTS/SETUP

Instruments

1. Laparoscopic entry device (14-gauge Veress needle, Hasson cannula, Visiport, or Optiview)

2. Four additional trocars (5 mm with optional 10/12 mm)
3. Two needle drivers
4. Optional endoscopic suturing device (e.g., EndoStitch) with nonulcerogenic suture (i.e., avoid silk)
5. Clip applicators (5 or 10 mm)
6. Laparoscopic bowel (e.g., Babcock) grasper
7. Atraumatic liver retractor (Nathanson or fan type)
8. Curved dissectors (e.g., Maryland)
9. Electrosurgical device:
 - a. L-shaped hook coagulator/dissector, preferably combined with laparoscopic suction and irrigator device or
 - b. Optional electrosurgical dissection device (e.g., Harmonic scalpel, LigaSure, or EnSeal)
10. Optional laparoscopic staplers (usually Blue load [1.0-mm tissue compression] for body of stomach) or Green (2.0 mm) if thick tissue
11. Absorbable monofilament sutures
12. Optional fibrin sealant

Preoperative preparation

Prophylaxis against venous thromboembolism is provided before induction of anesthesia.⁶

Operating room setup

The patient can be in either the supine position or the modified lithotomy position (**Figure 58.1**). A “bean bag” cushion is preferred to allow patient positioning to a reverse Trendelenburg position of 15°, especially for morbidly obese patients. One or both arms may be tucked. Urinary catheter and nasogastric tube are placed after induction of anesthesia. The abdomen is prepared and draped in standard fashion for laparotomy.

If the modified lithotomy position is used, the camera holder is usually on the patient's left, and the first assistant is on the patient's right. Video monitors are placed on either side of the patient's head.

The insufflation tower and suction device may be placed at the foot of the operating room table to ease the management of that tubing.

TECHNIQUES

Access and port placement

The peritoneum is entered approximately 13 cm inferior to the epigastrium or at the umbilicus using any of the previously mentioned laparoscopic entry devices (**Figure 58.2**). After pneumoperitoneum is established, the abdomen is inspected. Additional ports are usually placed, including a liver retractor in the epigastrium, bilateral subcostal 5-mm ports, and one additional dissection port in the left paramedian region.

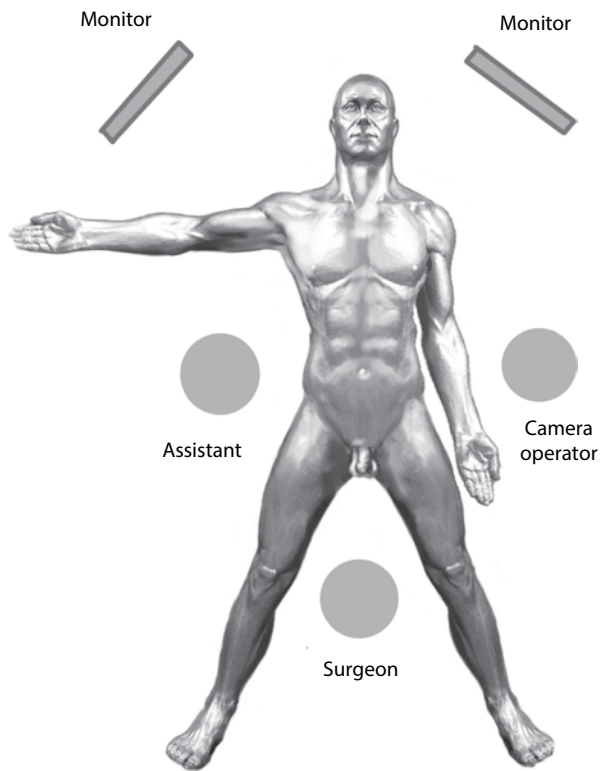


Figure 58.1 Positioning for PUD surgery.

Procedure

EXPOSURE

The left lobe of the liver is retracted anterolaterally with a liver retractor to expose the area of perforation.

LAPAROSCOPIC REPAIR OF PERFORATED DUODENAL ULCER

1. A sample of the spillage should be sent for Gram stain and culture and include fungal analysis in the more ill

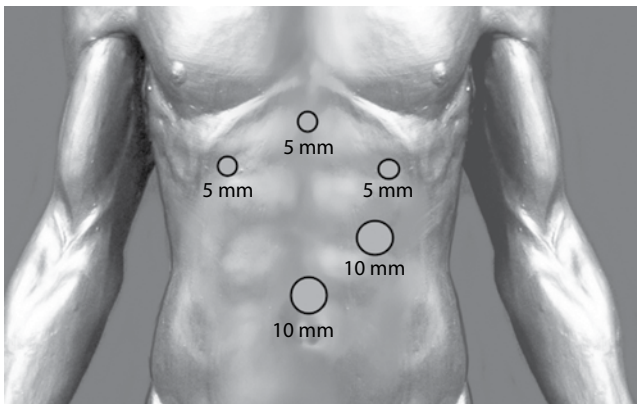


Figure 58.2 Trocar locations for PUD surgery.

patient. Soilage is suctioned along with abscess before irrigation is initiated. Associated lesions are noted and managed if necessary (adhesions, biliary cyst, cholecystitis, and appendicitis).

2. The mobility of the inflammatory tissue is related to the interval of time between perforation and the time entering the operating room.
 - a. If there is enough mobility, the identified perforation is closed transversely to avoid narrowing of the duodenal lumen. An intracorporeal knot is tied with interrupted nonulcerogenic suture material like Vicryl (polyglactin 910), but the suture tails are left long (Figures 58.3 through 58.5). Then a tongue of omentum is secured to the repair site using these tails as a modified Graham patch.

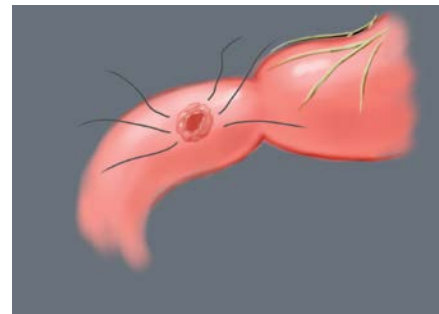


Figure 58.3 PUD perforation suture repair.

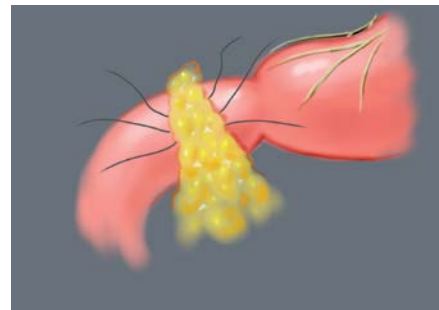


Figure 58.4 PUD perforation buttressed with omental patch, including additional sutures for security.



Figure 58.5 PUD perforation omental patch.

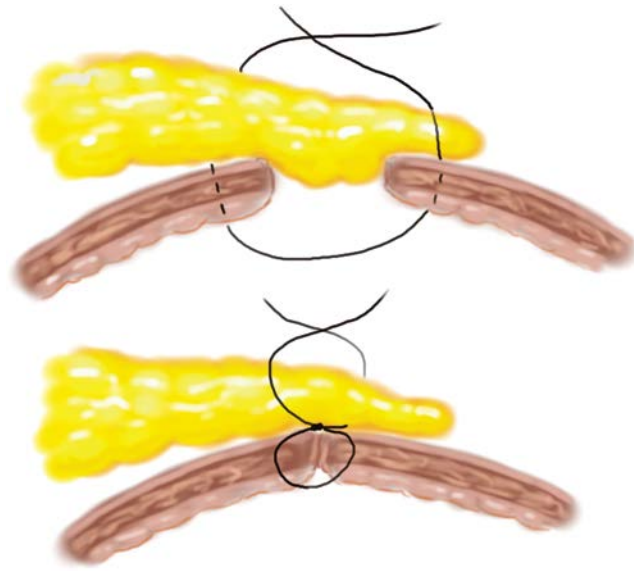


Figure 58.6 True and modified Graham patch.

- b. If the edges of the perforation are too friable or too nonmobile to close, then the tongue of omentum is placed to cover the hole in the duodenum, and the suture is tied through the omentum in the true Graham patch method (Figure 58.6).

Exposure of the hiatus

1. With a Babcock grasper, the stomach is retracted inferiorly, and the gastrohepatic ligament or pars flaccida is entered (Figure 58.7). This avascular tissue is clear even in obese patients.
2. After the phrenoesophageal ligament or pre-esophageal peritoneum is opened, dissection continues with minimal electrosurgical devices to identify the right crus and the esophagus.
3. Some surgeons prefer removing the nasogastric tube when working around the esophagus to minimize inadvertent perforation with the graspers, whereas other surgeons use the nasogastric tube to facilitate the dissection.
4. The anterior vagus nerve, recognized by its white color and firm consistency, is usually identified with relative ease.
5. As the right crus is retracted laterally, the posterior vagus nerve can be identified.
6. Prior to any vagotomy, the components of the vagal nerves should be identified, including the hepatic and celiac branches, and both nerves of Latarjet.

Posterior truncal vagotomy

1. With gentle traction on the nerve, adhesions are lysed to mobilize the nerve away from the esophagus.

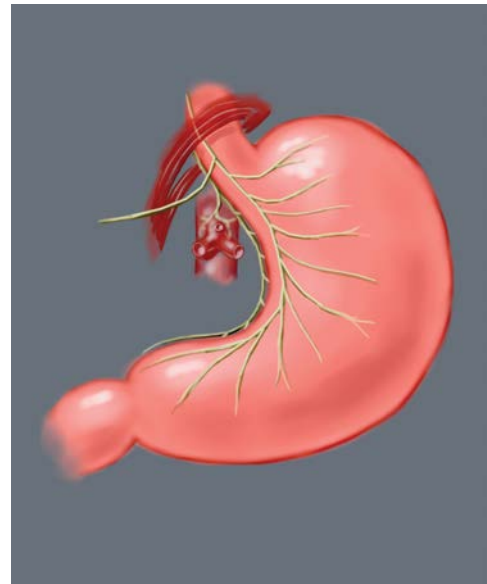


Figure 58.7 Exposure to vagal nerve trunks.

2. A short segment about 1 cm in length is clipped and excised and sent for histological verification of neural tissue (Figure 58.8).
3. An anterior truncal vagotomy could be performed but would require a subsequent drainage procedure like pyloroplasty and is no longer advocated in the modern era.¹³

Anterior vagal nerve management

Three techniques to manage the anterior vagus nerve in a highly selective manner and thus obviate the need for a drainage procedure are discussed in the following sections.

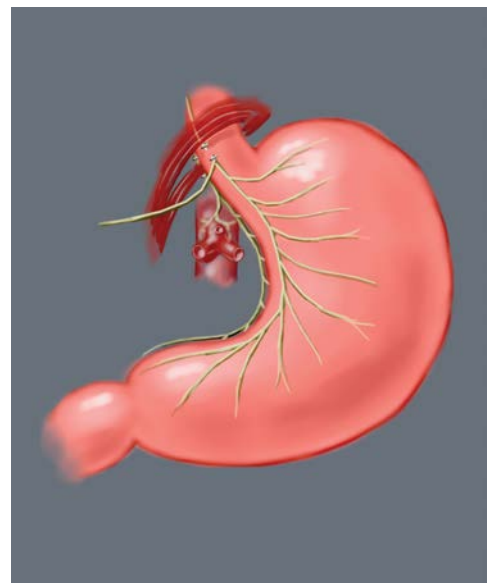


Figure 58.8 Posterior vagotomy.

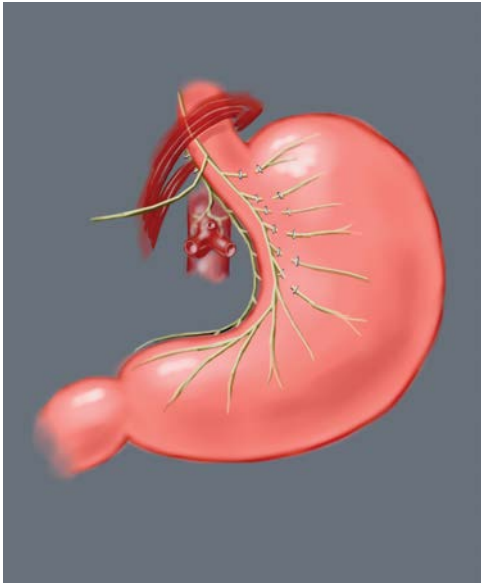


Figure 58.9 Highly selective (parietal cell) vagotomy.

ANTERIOR HIGHLY SELECTIVE (PARIETAL CELL) VAGOTOMY

This method translates directly from surgeons who are comfortable with the open technique (**Figure 58.9**). Historically, however, this approach has a higher rate of lesser curvature devascularization, subsequent delayed perforation, and thus increased mortality rate.

1. The previously identified anterior (left) vagal trunk is dissected free from the esophagus. To identify the proximal branches, the abdominal esophagus usually needs to be mobilized.
2. The hepatic branch of the anterior vagal trunk is preserved.
3. The proximal and distal margins may be marked with a loosely tied suture to preserve orientation, since subsequent bleeding may obscure visibility of each nerve branch.
4. Dissection starts 6 cm proximal to pylorus to preserve the crow's foot branches of the nerve of Latarjet. Doing so maintains the innervation to the pylorus and thus prevents the requirement for a drainage procedure.
5. All branches to the left of the esophagus should be divided between surgical clips to include the criminal nerve of Grassi.

ANTERIOR GASTRIC SEROMYOTOMY (MODIFIED TAYLOR PROCEDURE)

1. Starting at the esophagogastric junction at 1.5 cm from the lesser curve, the electrocautery device (25–30 Watts for the cautery device) is used to divide the serosal, oblique muscle, and circular muscle layers (**Figure 58.10**).
2. Cauterization stops approximately 6 cm from the pylorus at the level of the crow's foot.

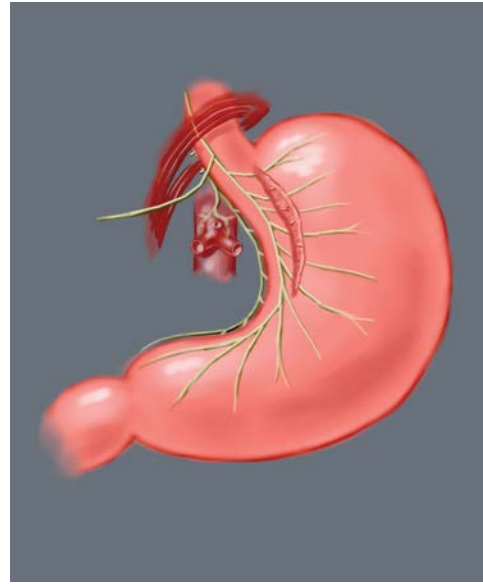


Figure 58.10 Anterior seromyotomy.

3. Similar to the technique for Heller myotomy, the remaining deep circular fibers are broken apart laparoscopically.
4. The submucosal layer adherent to the mucosa should be incised. The typical blue hue of the gastric mucosa will be easily identified. The seromyotomy should appear to be a 7.5-mm trench in the gastric wall. Air or methylene blue can be injected via the nasogastric tube to verify there is no perforation.
5. Two or three short vessels may be encountered during the incision and should be divided before starting the seromyotomy.
6. The seromyotomy is closed with an overlapping running suture, taking care to prevent vagal innervation.

ANTERIOR STAPLED LINEAR GASTRECTOMY

With newer technology, the stapled technique is faster than the seromyotomy:

1. An anterior fold of full-thickness gastric tissue is elevated with graspers about 1 cm.
2. An endoscopic stapler is fired across the base, excising a full-thickness segment of stomach and thus dividing the anterior gastric vagal branches (**Figure 58.11**).
3. The staple line proximal and distal margins are the same as described in the seromyotomy previously discussed, preserving pyloric innervation.

The operative field is suctioned and irrigated, and hemostasis is verified. A drain may be placed.

Under direct vision, trocars are withdrawn to verify hemostasis, and the trocar sites are closed in the usual fashion.

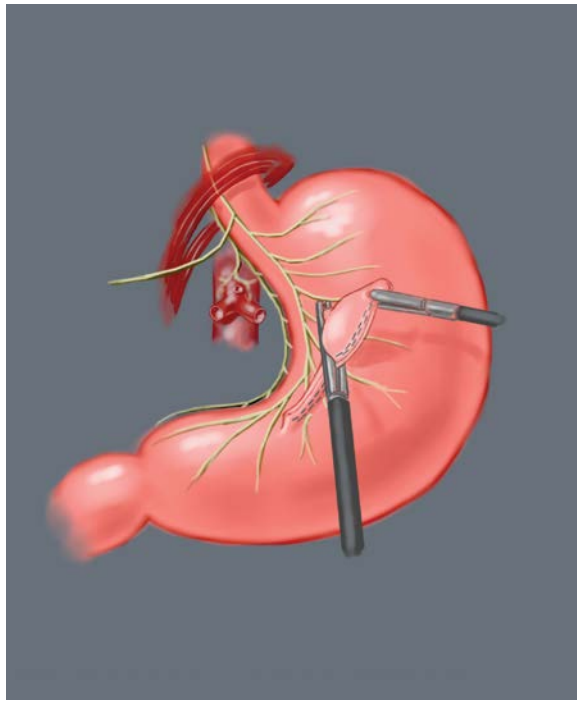


Figure 58.11 Anterior stapled linear gastrectomy, laparoscopic.

Postoperative care

Venous thromboembolism prophylaxis is continued, if indicated.

For the perforated PUD patient,

1. Broad-spectrum antibiotics are continued for a week, depending on the soilage and clinical status. In critically ill patients, antifungals should be considered.
2. Testing and treatment for *H. pylori* are critical, readily done by stool antigen testing.
3. Nasogastric tube decompression is continued for a few days.
4. An upper gastrointestinal fluoroscopic exam helps to exclude persistent leak.
5. If no leak exists, then the nasogastric tube is removed, and oral intake is restarted.

For the elective intractability procedure, postoperative care includes the following:

1. Nasogastric tube is usually removed within 24 hours postoperatively. Diet may be advanced up to soft mechanical.
2. Postoperative antibiotics are continued only if indicated.

PITFALLS/POINTERS/TROUBLESHOOTING

1. Complications of the vagal nerve ligation include intra-operative injury to the esophagus (especially if grasped with instrument), stomach, liver, colon, or vessels close to areas of dissection.¹⁷
2. By leaving the neurovascular bundle of the posterior nerve, ischemic necrosis is rare.
3. Delayed hemorrhage along the anterior gastric wall can occur if vessels are coagulated with standard electrosurgical device rather than clipped or sealed with one of the more modern electrosurgical devices.
4. Inferior retraction of the stomach is key to identifying the anterior vagal nerve during dissection.

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Resection of nonadenomatous gastric tumors

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INTRODUCTION

Nonadenomatous gastric tumors represent a wide spectrum of diseases ranging from benign entities, such as leiomyoma, schwannoma, pancreatic heterotopia, gastric cavernous hemangiomas, and lipomas to malignant tumors, such as gastrointestinal stromal tumor (GIST), leiomyosarcoma (LMS), type I-III gastric carcinoid, and lymphoma ([Table 59.1](#)). Because each tumor type is derived from a different cell of origin, their pathobiology, behavior, and requirement for medical and/or surgical management are distinct. Frequently, small tumors are incidentally identified on upper endoscopy (e.g., bulge underlying the gastric mucosa) or at surgical exploration. Larger tumors often cause symptoms, including nonspecific abdominal symptoms (e.g., nausea/vomiting, discomfort, pain, distension, or early satiety), chronic bleeding (e.g., anemia or melena), acute bleeding (e.g., hematemesis due to intraluminal ulceration), acute abdominal pain (e.g., tumor rupture into itself or the peritoneal cavity), or obstruction.

Due to differences in the natural history and biology of these tumors, the roles of medical and surgical treatments vary. Therefore, a careful diagnostic evaluation of each tumor is important before determining the optimal management for each patient. Herein, we discuss the biology of malignant tumors, as well as the multidisciplinary diagnosis and staging of these tumors. We then review the indications, goals, and approaches to gastric tumor resections via endoscopic, laparoscopic, laparo-endoscopic, and open approaches followed by a brief discussion of adjuvant therapy for malignant tumors.

MALIGNANT, NONADENOMATOUS GASTRIC TUMORS

Gastrointestinal stromal tumor

Overall, GIST represents the most common sarcoma of the gastrointestinal (GI) tract. These tumors, which can arise

anywhere within the GI tract, are thought to arise from the pacemaker cells of the gut known as the interstitial cells of Cajal (ICC).¹ In 1998, Hirota and colleagues reported that GIST was initiated by gain-of-function mutations in the *KIT* (c-*KIT*, CD117) gene and are associated with *KIT*-positive immunostaining.² We now know that these tumors are molecularly heterogeneous and also characterized by gain-of-function mutations in other oncogenes, including *PDGFRA*, *RAS*, and *BRAF*. Many studies have characterized the incidence of GIST in the United States, Europe, and Asia. The annual reported incidence appears to vary by region: 3.2–6.8 cases per million persons in the United States; 2.1–14.5 cases per million persons in Europe; and 11.3–19.7 cases per million persons in Asia. GIST most commonly occurs in the stomach, and the most common risk factors include older age, male sex, and Black or Asian/Pacific Islander race. The average age at diagnosis ranges from 62 to 75 years old. The malignant behavior of GIST is highly variable and determined by tumor size, location, histopathologic features, particularly the mitotic index, and underlying tumor genomics. The disease spectrum ranges from “small GIST” (i.e., <2 cm) to massive intra-abdominal tumors. Patients with small GIST are often asymptomatic, and tumors are typically discovered incidentally during endoscopic procedures or by cross-sectional radiologic imaging. To date, we have lacked a clear understanding of the clinical significance of small GIST. The National Comprehensive Cancer Network (NCCN) and European Society of Medical Oncology (ESMO) guidelines for the surveillance and management of GIST <2 cm have been deemed controversial due to the lack of evidence-based approaches. However, recent data suggest that patients with resected GIST <2 cm and no additional cancers have a 5-year GIST-specific mortality of 12.9%.³ This raises the question as to how to best manage or follow these patients. At present, there is only consensus that GISTs >2 cm should be resected, if feasible.⁴ However, the management of asymptomatic, incidentally identified GIST <2 cm remains unclear.

Table 59.1 Differential diagnosis of nonadenomatous gastric tumors and their cells of origin

Tumor	Cell of origin
<i>Benign</i>	
Leiomyoma	Smooth muscle cell
Schwannoma	Schwann cell
Pancreatic heterotopia	Ectopic pancreatic acini
Gastric cavernous hemangiomas	Endothelial cell
Lipomas	Adipocyte
<i>Malignant</i>	
Gastrointestinal stromal tumor (GIST)	Interstitial cell of Cajal
Leiomyosarcoma (LMS)	Smooth muscle cell
Gastric carcinoids	Neuroendocrine cell
Lymphoma	Immune cell

Lymphoma

Primary gastric lymphoma represents less than 15% of gastric malignancies and about 2% of all lymphomas. However, the stomach is a very common extranodal site for lymphomas to occur. In general, these tumors are treated with systemic chemotherapy with or without radiation, depending on the

specific lymphoma subtype. Surgical consultation is obtained when tissue is required for diagnosis or the tumor is resistant to chemotherapy and causes significant symptoms, such as gastric outlet obstruction. A diagnostic biopsy can be performed with endoscopy or laparoscopy, and tissue should be sent to the pathology in a fresh manner (i.e., not in formalin). A core biopsy is preferred over fine needle aspiration to provide adequate tissue for flow cytometric analysis, which assesses for cell surface markers that are important for distinguishing lymphoma subtypes and dictating treatment.

Gastric carcinoids

Gastric carcinoids represent about 4% of all gastrointestinal neuroendocrine tumors and 1% of gastric neoplasms. They are divided into three types that have distinct presentations, pathobiologies, and treatments guided by general guidelines ([Table 59.2](#)). To summarize, type I and II patients are managed with endoscopic resection for tumors <1 cm. Local excision with or without antrectomy is performed for 1- to 2-cm type I/II carcinoids or when there are more than five type I carcinoids. Partial or total gastrectomy with lymphadenectomy is recommended for

Table 59.2 Overview of type I–III gastric carcinoids

	Type I	Type II	Type III
Percent of gastric carcinoids	70%–80%	5%	20%
Associations	Chronic atrophic gastritis	Zollinger–Ellison syndrome in patients with multiple endocrine neoplasia (MEN) type 1	None (sporadic)
Age	>50 years old		>50 years old
Gender	Female > Male	Female = Male	Female < Male
Gastrin level	Elevated	Elevated	Normal
Gastric acid level	Low	High	Normal
Tumor type	Nodular or polypoid	Small and multiple	
Cell of origin	Enterochromaffin-like (ECL) cells secondary to a hypergastrinemic state	ECL cells secondary to a hypergastrinemic state	ECL or X cells
Tumor size	Often <1 cm	Often <1.5 cm	
Rate of metastasis	5%	7%–12%	Regional lymph nodes (55%) and liver (24%)
5-year survival	>95%	70%–90%	<35%
Hormone production	Serotonin	Serotonin	5-hydroxy-tryptophan (5-HT)
Carcinoid syndrome	No	No	Yes (atypical flushing)
Treatment	Endoscopic resection if <1 cm	Endoscopic resection if <1 cm	Partial or total gastrectomy + lymphadenectomy if >2 cm
	Local excision ± antrectomy (gastrin-producing cells) for 1–2 cm or >5 lesions	Local excision ± antrectomy (gastrin-producing cells) for 1–2 cm	
	Partial or total gastrectomy + lymphadenectomy if >2 cm	Partial or total gastrectomy + lymphadenectomy if >2 cm	

Source: Based on Wardlaw R, Smith JW. 2008;8(4):191–6.⁵²

type I/II carcinoids >2 cm. Partial or total gastrectomy with lymphadenectomy is recommended for all type III tumors >2 cm.

Leiomyosarcoma

Gastric LMS is rare and represents approximately 1% of gastric malignancies. These tumors tend to occur in younger females and are often localized.⁵ They are most often located in the gastric fundus or along the greater curvature of the stomach. In a study of 574 patients using the Surveillance, Epidemiology, and End Results (SEER) database, the median overall survival for all gastric LMS patients was 36 months, and 72 months for nonmetastatic patients. Resection offers the best chance for improved survival.

DIAGNOSIS

Having presented some background about the various malignant tumor types, we now focus on the general management of these tumors. Many nonepithelial gastric tumors are identified incidentally at the time of upper endoscopy, where they appear as a smooth, firm, round submucosal mass that may be endophytic (i.e., protruding into the gastric lumen) or exophytic (i.e., protruding from the gastric wall into the peritoneal cavity) (Figure 59.1).⁶ Since these tumors are not derived from the gastric epithelium itself, they often have normal overlying mucosa, or if large enough, may have ulceration and/or evidence of bleeding.⁶ In light of their growth pattern within the gastric wall, standard endoscopy alone is limited in its ability to secure a diagnosis.^{7,8} This is especially the case with exophytic tumors (Figure 59.1c). Moreover, given that these masses are submucosal, standard endoscopic biopsy forceps are minimally useful as the pathology from such biopsies often yields normal mucosa and does not provide a deep enough tissue sample for a diagnosis.⁷ As a result, endoscopic ultrasound (EUS) is often necessary to provide additional diagnostic information, including (1) tumor shape, (2) tumor size, (3) layer of origin, and (4) echogenicity (Figure 59.1b and d). However, in the case of larger tumors (>5 cm), EUS is limited by a narrow field of view, and may underestimate the extent of disease.⁹ It is often not possible to distinguish one tumor type from another just using EUS. Therefore, EUS-guided fine needle aspiration (FNA) or Tru-Cut biopsy (TCB) are now the preferred methods for obtaining adequate tissue in order to secure a diagnosis. In comparing FNA with TCB, the latter is preferable, if possible, since adequate tissue is available for tumor histology and immunohistochemical staining. But, FNA only allows for assessment of tumor cytology, which may not be adequate for distinguishing spindle cell neoplasms such as GIST, LMS, schwannoma, and leiomyoma. In the case of GIST, the diagnostic accuracy of FNA and TCB has been reported to approach 80% or higher.^{10,11} Additionally,

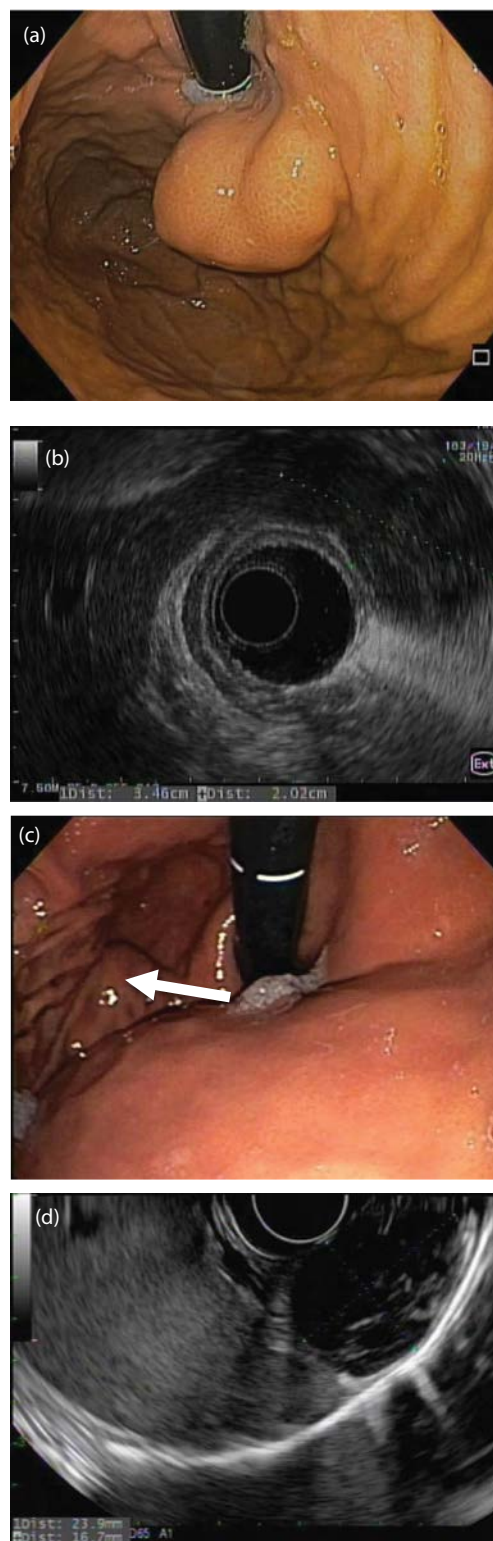


Figure 59.1 Variable growth patterns of nonadenomatous gastric tumors. Images of a 3.5-cm $\times$ 2.0-cm endophytic leiomyoma adjacent to the gastroesophageal junction on (a) endoscopy and (b) endoscopic ultrasound (EUS). Images of a 2.4-cm $\times$ 1.7-cm exophytic GIST adjacent to the gastroesophageal junction on (c) endoscopy (white arrow) and (d) EUS.

performing EUS-TCB is faster than performing endoscopic submucosal biopsies while still providing sufficient tissue for pathological diagnosis.¹² Finally, it is noteworthy that EUS-guided biopsies are preferred to percutaneous biopsies in the case of evaluating gastric tumors due to lower risk of hemorrhage and tumor seeding.¹³

IMAGING STUDIES: ADDITIONAL DIAGNOSTIC WORKUP AND CANCER STAGING

Imaging studies are usually necessary to evaluate and stage gastric tumors. The role of plain radiography is limited in gastric tumor evaluation; however, it may occasionally identify larger, incidental tumors like GISTs, which may demonstrate mass effect on the gastric bubble or calcifications.¹⁴ The primary imaging modalities include computed tomography (CT) and magnetic resonance imaging (MRI) with contrast enhancement, as well as positron emission tomography (PET) in some circumstances.¹ All of these modalities have the potential to characterize the extent of disease, and may be useful to assess responses to neoadjuvant therapy in the case of malignant tumors.

Contrast-enhanced CT is the initial modality of choice for the characterization of gastric tumors and for evaluating the extent of disease.¹⁵ However, CT alone often cannot distinguish benign from malignant tumors (Figure 59.2). For example, while a GIST may have heterogeneous enhancement with calcification, ulceration, cystic degeneration, central necrosis, or foci of air with fistula formation on CT, none of these findings necessarily correlate with risk of malignancy.^{9,16,17} Despite all of the strengths of CT for staging disease and evaluating anatomy, CT has limitations, including difficult analysis of small lesions and an inability to accurately identify the layers of the bowel wall that are involved.⁶ When CT images are inconclusive or CT is contraindicated, MRI is another option. Moreover, MRI has higher sensitivity for assessing small liver lesions. Alone or together, these cross-sectional imaging modalities are also necessary in the staging of possible malignant tumors. These should include CT of the chest, abdomen, and pelvis to assess for metastatic disease as the presence of extragastric lesions may alter the approach to management.

In contrast to benign gastric tumors, such as leiomyomas and schwannomas, most malignant gastric tumors are metabolically active and take up the radiolabeled glucose analog ¹⁸F-fluorodeoxyglucose (¹⁸FDG). As a result, ¹⁸FDG-PET has a high sensitivity (i.e., approximately 80%) for detecting GIST at initial presentation.¹⁸ However, GISTs can have variable ¹⁸FDG uptake, and only some tumors may be ¹⁸FDG-avid. As a result, PET is typically reserved for resolving ambiguous findings on CT or MRI, as well as for monitoring early response to neoadjuvant treatment. In phase II trials in patients with GIST, ¹⁸FDG-PET revealed responses within the first week of treatment in 69%–85% of patients.^{19,20} But, decreases in FDG uptake, as measured by changes in SUV_{max}, can occur as early as 24 hours after

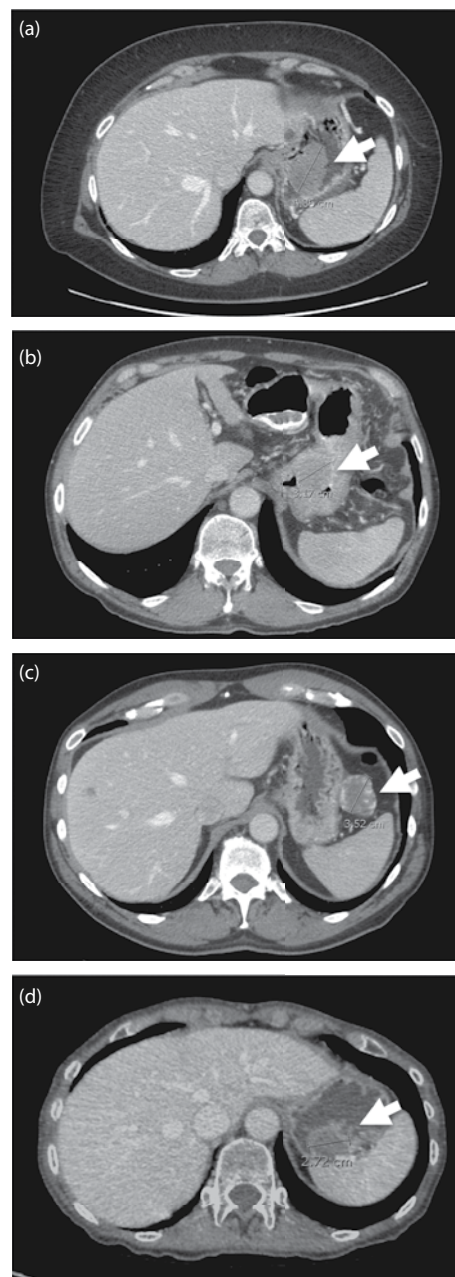


Figure 59.2 Benign and malignant nonadenomatous gastric tumors have similar appearance on CT scans. (a) Leiomyoma. (b) Schwannoma. (c) Hemangioma. (d) Gastrointestinal stromal tumor (GIST). White arrows indicate tumors.

initiating imatinib therapy. However, the change in CT density is the preferred approach to assess early tumor response in GIST.

INDICATIONS FOR RESECTION

In general, several factors should be considered for operative decision-making in patients medically fit for an operation. In addition to the patient's overall health and performance

status, their presenting symptoms should be considered. Their presentation should be coupled with the biology of the tumor (i.e., benign or malignant), tumor type, tumor grade, tumor size, tumor location, tumor number (i.e., metastatic or multifocal disease), involvement of adjacent organs, proximity to critical structures, and presenting signs. All patients with symptomatic tumors (whether benign or malignant), growing or large “benign” tumors, biopsy-proven malignant tumors, or tumors where a diagnosis cannot be obtained should be referred for surgical evaluation. Given the multiple factors to consider, a multidisciplinary approach is warranted. The following sections provide further insight into this decision-making process.

GOALS OF RESECTION

There are five key factors that should be considered in planning a gastric tumor resection. These include achieving microscopically negative margins, avoiding tumor rupture, sparing adjacent organs (if possible), performing lymphadenectomy only for diseases that have lymph node metastases (e.g., gastric carcinoid and rare GIST subtypes that frequently present in younger patients), and approaching the resection in a safe and appropriate manner (e.g., endoscopic resection, laparoscopic resection, laparoendoscopic resection, or open resection).

Margin status

The primary goal of resection of any nonadenomatous gastric tumor is to achieve total gross resection of the tumor. Ideally, this is achieved with microscopically negative margins (i.e., R0) while maintaining an intact tumor pseudocapsule and avoiding tumor rupture or spillage. While less of an issue with benign tumors, one should strive for this in all cases since the pathologic diagnosis may change following additional pathological review of the entire tumor. Nevertheless, a positive margin is not necessarily a reason to return to the operating room. In the case of GIST, the optimal margin of resection has not been well defined. In a retrospective review of a large multi-institutional cohort study, which included 819 patients and a median follow-up of 4 years, there was no statistically significant difference in recurrence-free survival (RFS) between patients who had undergone R0 versus R1 (i.e., microscopically positive margins) resections.²¹ Among patients treated with placebo or adjuvant imatinib for 1 year, the overall risk of recurrence following an R1 resection was 39% and 35%, respectively. In contrast, it was only 27% among R0 resection patients in both groups. Moreover, surgeons must also be aware of the fact that GISTs are highly vascular, friable tumors that are prone to rupture during surgical manipulation, which may lead to intraperitoneal tumor dissemination and an increased risk of recurrence.^{22,23} Upon further subset analyses of

the aforementioned study,²¹ the 3-year RFS rate for the R1 patients ($n = 21$) with tumor rupture was 60% versus 80% in the R1 patients without rupture ($n = 51$, HR 3.58, $p = 0.001$). Thus, the authors concluded that the risk of recurrence is driven by the presence of tumor rupture, but not microscopically positive margins. With these findings in mind, whether to reoperate after an R1 GIST resection needs to be determined on an individual basis. In contrast, grossly positive margins (R2) clearly portend a worse prognosis with significantly shorter disease-specific survival rates.²⁴ Thus, GIST and other submucosal gastric tumors should be handled with care in order to decrease the risk of rupture, which is clearly associated with increased risk of tumor recurrence, while attempting to achieve microscopically negative margins. With these principles in mind, an R1 resection may be tolerable for low-risk lesions (i.e., low mitotic index) with unfavorable tumor locations.²⁵

Organ-sparing resection

Complex multivisceral resections are known to be associated with increased postoperative morbidity. Therefore, most U.S. surgeons would recommend attempting to minimize the resection of adjacent organs (e.g., diaphragm, liver, spleen, pancreas, or transverse colon) during resection of a sarcomatous tumor (e.g., GIST or LMS), as long as it does not compromise the tumor capsule or lead to tumor rupture. In a study of 1,873 GIST and LMS cases in the SEER database of the National Cancer Institute, the authors showed similar outcomes for wedge and complete visceral resections of these tumors.²⁶ But, resection of adjacent organs in order to obtain an R0 margin status has been shown to increase morbidity.²⁷ Thus, it is important to carefully select patients for wider resections, while also considering neoadjuvant therapy (e.g., imatinib for GIST) in order to downsize the tumor and allow for a higher chance of an R0 resection and sparing of adjacent organs.

Role for lymphadenectomy

While benign tumors obviously do not metastasize to lymph nodes, lymphatic spread of gastric sarcomas is quite rare and most commonly only seen in younger patients with pediatric GIST. In one study of 699 adult GIST patients, there was a 1% rate of nodal involvement.²⁸ This most often occurred in patients under 40 years of age with epithelioid or mixed (e.g., epithelioid-spindle) histopathologies. These data have been confirmed in other small studies. As a result, lymphadenectomy is not routinely indicated in the surgical management of GIST or LMS.^{29,30} However, in cases where clinically or radiologically positive lymph node involvement is suspected, selective lymphadenectomy is recommended. In the case of gastric carcinoids, lymphadenectomy is dictated by the type and size of the tumor (Table 59.2).

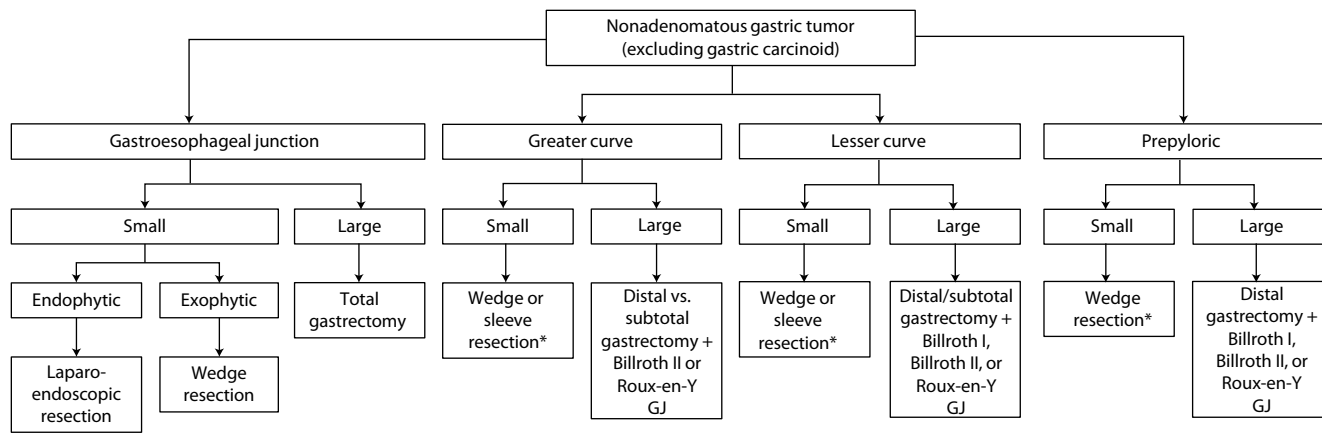


Figure 59.3 Overview of recommended approaches to resecting gastric nonadenomatous tumors (exclusive of gastric carcinoids) based on tumor location and size. *Indicates if the gastric lumen is not compromised. (GJ, gastrojejunostomy.)

Location dictates operation

As nonadenomatous tumors can develop anywhere within the stomach (e.g., gastroesophageal junction, greater curve, lesser curve, or prepyloric region), an algorithmic approach of a wide variety of surgical procedures may be employed in their resection (Figure 59.3). For example, a small gastric GIST or a benign tumor along the greater curve may only require a simple wedge resection, since in most surgical series equivalent long-term results were obtained using a wedge resection or partial gastrectomy.^{31–34} A large tumor, or one positioned near the gastroesophageal junction or pylorus may necessitate a more formal resection and reconstruction (e.g., total gastrectomy and distal gastrectomy, respectively) due to anatomical reasons and not necessarily biological factors. As a result, there is an assortment of techniques that are currently utilized in the resection of these tumors. Herein, we mostly focus on GIST as an example given that (1) it is the most common nonadenomatous malignancy in the stomach; (2) the majority of publications focus on this disease; and (3) similar approaches can be extrapolated to LMS, as well as benign tumors that require resection.

OVERVIEW OF OPERATIVE APPROACHES AND TECHNIQUES

Surgical approaches for treating nonadenomatous gastric tumors range from minimally invasive endoscopic resections (e.g., type I–II carcinoids) to extensive laparotomies for resection of malignant tumors (e.g., GIST or LMS) with adjacent organ involvement (Figure 59.3). To reiterate, the goal of surgical treatment is complete resection with negative microscopic margins, an intact pseudocapsule, and avoidance of tumor rupture. Because lymph node metastases are uncommon, lymphadenectomy is not generally indicated for sarcomatous tumors, while perigastric

lymphadenectomy is generally only part of the management of certain type I–III carcinoids (Table 59.2). Following the algorithmic approach in Figure 59.3, we focus on the management of tumors based on location.

RESECTION APPROACHES BASED ON TUMOR LOCATION AND SIZE

Laparoendoscopic resection of gastroesophageal junction tumors

Several single patient case reports, and more recently a larger single institution case series of 14 patients,³⁵ have reported combining laparoscopic and endoscopic techniques to resect endophytic gastric submucosal tumors. The latter study included tumors, including GIST, near the gastroesophageal junction (Figure 59.2a and b), which have historically warranted proximal or total gastrectomies,³¹ as well as endophytic tumors along the lesser curve of the stomach or arising from the posterior wall of the stomach (Figure 59.4a). The laparoendoscopic technique is performed using 5-mm and 12-mm balloon trocars that are placed intragastrically under direct visualization via an endoscope positioned in the stomach (Figure 59.4b). This offers advantages of an extra working port with the endoscope without having to make more than two gastrotomies for trocars placed into the stomach. Using this approach, full-thickness gastric tumor resections can be performed using a stapler placed intragastrically (Figure 59.4c). Moreover, tumors smaller than 4 cm can be placed in an Endo Catch bag and removed via the mouth in order to avoid extending gastrotomies beyond 12 mm. However, this approach is still early in its development. In the largest study reported, two patients (14.3%) had postoperative staple line bleeding that required repeat endoscopy, while at 12-month follow-up visits, one GIST patient (10%) had tumor recurrence. Thus, continued investigation of this

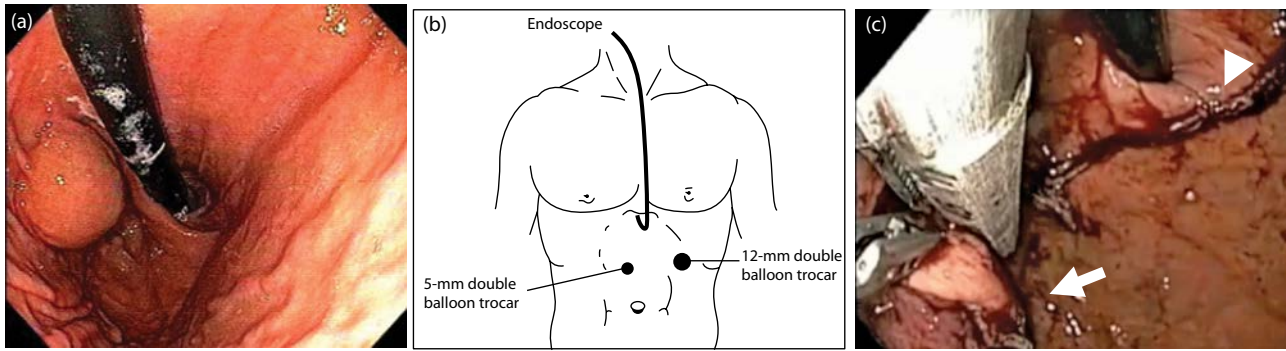


Figure 59.4 Laparoendoscopic transgastric resection of a GIST at the gastroesophageal junction. (a) Endoscopic view of an endophytic submucosal GIST adjacent to the gastroesophageal junction. (b) Laparoscopic transgastric balloon port placement for intragastric tumor resection. (c) Sequential full-thickness and submucosal stapler firing to resect GIST (white arrow indicates tumor specimen).

approach needs to be performed in order to further validate it as safe, effective, and oncologically sound. Taken together, a personalized surgical approach should be tailored to each patient based on several factors including tumor-related factors (e.g., histology and location), the surgeon's technical skill set, and patient factors.

Laparoscopic and open resection of tumors of the greater and lesser curve

In general, all gastric tumors that are distant from the gastroesophageal junction or the pylorus may be adequately resected with a gastric wedge resection, in lieu of partial, subtotal, or total gastrectomy. The lack of need for lymphadenectomies, combined with advances in minimally invasive techniques, have resulted in wider acceptance of minimally invasive approaches for resecting larger GIST and other submucosal tumors.^{35–37} Furthermore, this approach has been associated with shorter hospital stay, less pain, improved cosmesis, and decreased morbidity.^{35,38} These benefits occur in the absence of increased rates of local recurrences, port site recurrences,³⁶ or effects on long-term survival.^{39,40} As compared with a laparoscopic approach, an open approach allows for additional exposure and mobilization of larger tumors. While many single institution studies have associated an open approach with longer postoperative hospital stay, greater blood loss, and longer operation times, this may reflect a selection bias, because large tumors may not be amenable to resection by minimally invasive approaches. Most recently, a meta-analysis, including 7 of 189 reported retrospective studies, demonstrated that laparoscopic resection of gastric GIST is safe and effective and associated with a shorter length of hospital stay, but there were no differences in terms of operative time, adverse events, estimated blood loss, overall survival, or recurrence rates as compared to open resection.⁴¹ Thus, laparoscopic techniques are now considered appropriate for gastric GIST resection ranging in size from 2 cm to 8 cm without additional risk of complications or recurrence.

When planning a resection of a greater or lesser curve of the stomach, the size and location of the tumor, as well as the malignant potential of the tumor should be carefully considered. Small exophytic tumors in the midstomach are most amenable to laparoscopic wedge or sleeve resection given the redundancy of the gastric fundus. The goals of resection should be minimal tumor manipulation and grossly/microscopically negative margins. The stomach should be adequately mobilized by takedown of the short gastric arteries with care to preserve the blood supply from the gastroepiploic artery where possible. Resection can be carried out with multiple loads of an endoscopic stapler of the operator's choice. Attention should be paid to the thickness of stomach tissue, with an appreciation that the thickness of the stomach wall increases with distance from the gastroesophageal junction. The height and length of the stapler load should be selected appropriately to ensure proper approximation of the tissues (Figure 59.5).⁴² It is important to remember that these operations can be technically challenging, since tumors like GIST are highly vascular, friable tumors that can have cystic or necrotic components, making them easily prone to rupture during surgical manipulation. Given less sensitivity to touch with laparoscopic instruments, sometimes it may be more prudent to resect a tumor via an open approach, even if it is small, since the risk of recurrence is significantly increased by intraperitoneal tumor dissemination.⁴³

Laparoscopic and open resection of prepyloric tumors

Besides tumors along the lesser curve, or in close proximity to the gastroesophageal junction, tumors adjacent to the pylorus can be difficult to wedge resect as well. Therefore, resection may require distal or subtotal gastrectomy followed by reconstruction with one of three methods (Figure 59.6). These include a Billroth I anastomosis that may be performed between the stomach and proximal duodenum when there is adequate length of stomach to allow a tension-free

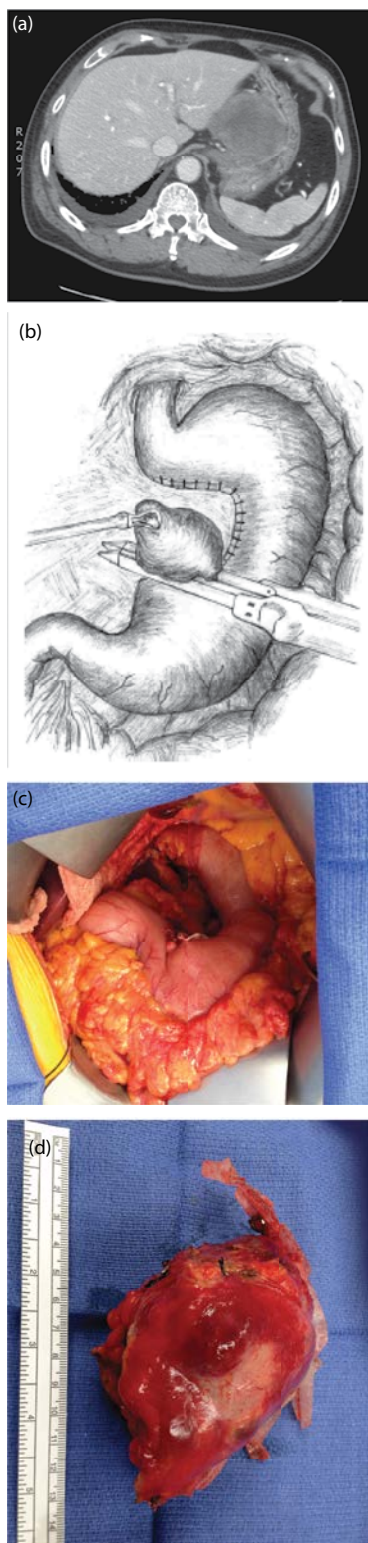


Figure 59.5 Resection of GIST along the lesser curve of the stomach. (a) CT image of a large exophytic GIST along lesser curve of the stomach, which abuts the left hemi-liver. (b) A stapled gastric wedge resection along the lesser curve of the stomach. (c) Gastric remnant following tumor resection of the mass in panel (a). (d) Tumor specimen with adjacent staple line. [(b) Adapted from Ye LP et al. *Surg Endosc* 2014;28[2]:524–30.]

anastomosis, a Billroth II anastomosis may be performed between the stomach and proximal jejunum via antecolic and retrocolic approaches, or a Roux-en-Y gastrojejunostomy anastomosis may be performed between the stomach and jejunum in order to allow for additional length of the bowel to reach the stomach, as well as to prevent biliopancreatic, alkaline reflux into the stomach. But, in the case of pyloric antrum/canal tumors removed via a wedge resection, the surgeon should be cognizant that tumor resection can create a gastric outlet obstruction due to gastric kinking, despite having an adequate lumen (Figure 59.7). If this is identified on endoscopy at the time of surgery, a distal gastrectomy should be performed in order to avoid this complication. In summary, whether a laparoscopic or an open approach is employed, oncologic principles should be followed as even “benign” tumors may have false-negative preoperative biopsies or may harbor small foci of malignancy.

Endoscopic submucosal resection

In the last decade, partial-thickness endoscopic submucosal resection has gained limited popularity for treating small (i.e., generally <3.5 cm) submucosal gastric tumors, which are often benign.¹ Clearly less invasive than a laparoscopic or open operation, this approach also has shorter operation times. However, the evidence for this approach is limited to several small retrospective single-institution case series.^{45,46} In one such study of 85 patients, including 25 gastric tumors, 9.4% of patients developed a pneumothorax, subcutaneous emphysema, and/or pneumoperitoneum.⁴⁴ Moreover, the overall rate of complications was 70% in patients with tumors arising in the deep muscularis propria and 26.3% in patients with GIST. Moreover, this technique has been associated with a high rate of positive margins (e.g., 7.8%–25.7%)^{43,44} and perforation,⁴⁷ as compared with other procedures.⁴⁸ As a result, this approach is not generally recommended at this time.

Natural orifice transluminal endoscopic surgery resection

While enthusiasm for natural orifice transluminal endoscopic surgery (NOTES) has waned in recent years, transvaginal NOTES gastrectomy has been reported in one patient with a hemorrhagic gastric lipoma and another with a gastric GIST.⁴⁹ While feasible and safe in this report, the wide acceptance and application of this approach seems limited, and there are no data on long-term oncologic outcomes.

ADJUVANT THERAPY FOLLOWING RESECTION OF MALIGNANT TUMORS

While there is no proven role for adjuvant chemotherapy in patients with gastric carcinoid or LMS, imatinib (Novartis, Basel, Switzerland) can further improve patient outcomes

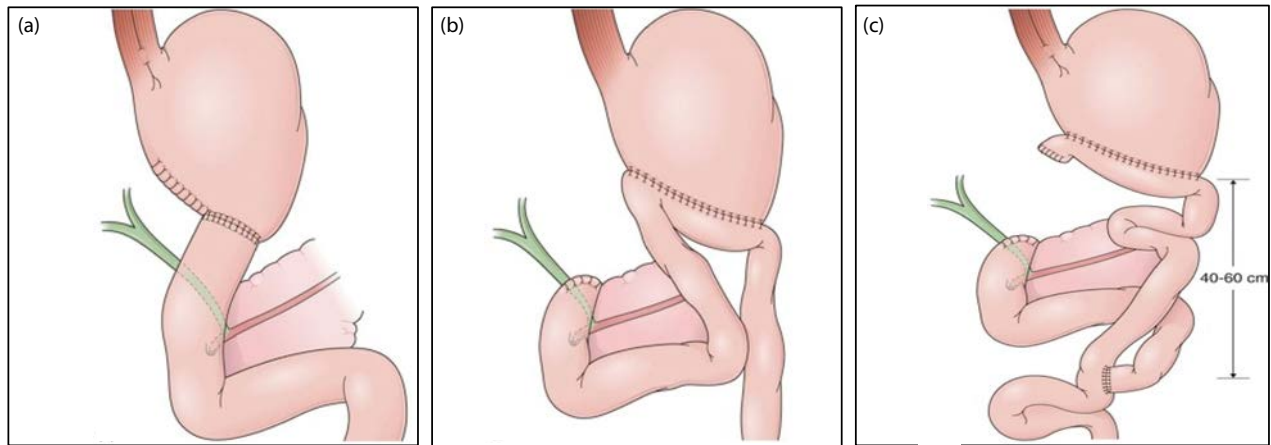


Figure 59.6 Types of reconstructions following distal or subtotal gastrectomy. (a) Billroth I anastomosis may be performed between the stomach and proximal duodenum when there is adequate length of stomach to allow a tension-free anastomosis. (b) Billroth II anastomosis may be performed between the stomach and proximal jejunum via antecolic and retrocolic approaches. (c) Roux-en-Y gastrojejunostomy anastomosis may be performed between the stomach and jejunum in order to allow for additional length of the bowel to reach the stomach, as well as to prevent biliopancreatic, alkaline reflux into the stomach. (Adapted from AB Feitoza, *Chapter 11: Postsurgical endoscopic anatomy, Clinical Gastrointestinal Endoscopy*, 2nd ed, <http://clinicalgate.com/postsurgical-endoscopic-anatomy/>.)

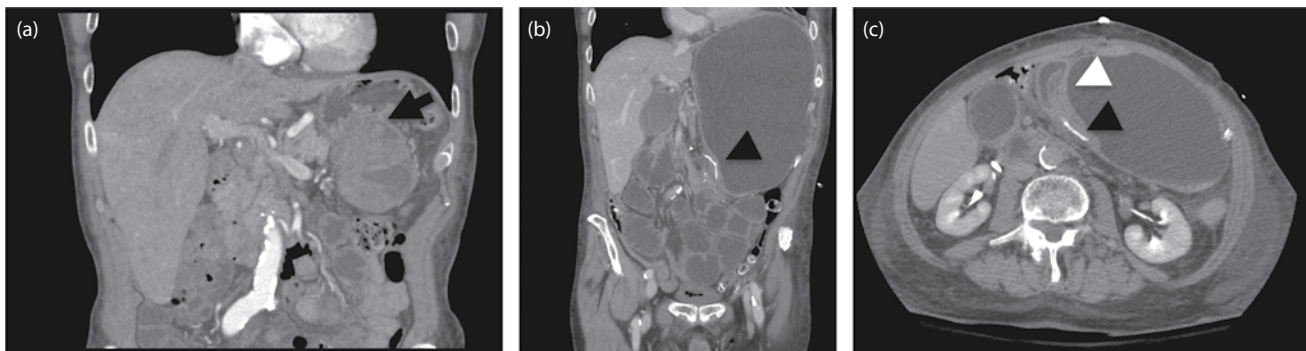


Figure 59.7 Resection of a pyloric antrum/canal gastrointestinal stromal tumor (GIST) complicated by postoperative gastric outlet obstruction. (a) An 86-year-old male presented with chronic anemia. CT, upper endoscopy, and endoscopic ultrasound with Tru-Cut biopsy revealed a pyloric antrum/canal spindle cell neoplasm (arrow) consistent with a GIST based on immunohistochemical staining. (b and c) Following a stapled gastric wedge resection that left the patient with a 3.5-cm gastric outlet, the patient developed a gastric outlet obstruction distal to the staple line (black arrowhead) secondary to kinking of the stomach on itself (white arrowhead). This potential complication can be identified intraoperatively by performing an upper endoscopy with gastric insufflation, which will reproduce the same kinking effect caused by angulation of the stomach despite a wide lumen. If identified, a distal gastrectomy should be performed in order to avoid this complication.

when used as adjuvant therapy in selected patients with GIST. The randomized, double-blind, placebo-controlled American College of Surgeons Oncology Group (ACOSOG) Z9001 phase III study showed that adjuvant imatinib significantly reduced GIST recurrence in patients with tumors ≥ 3 cm in size: the 1-year RFS rate was 98% with imatinib versus 83% with placebo ($p < 0.0001$).⁴⁹ Subsequently, to explore whether increasing the duration of imatinib therapy would result in improved RFS at long-term follow-up, the open-label SSGXVIII/AIO (Scandinavian Sarcoma Group/Sarcoma Group of the Arbeitsgemeinschaft

Internistische Onkologie) phase III trial randomized patients who underwent gross resection of primary KIT-positive GIST to receive 1 or 3 years of adjuvant imatinib (400 mg/day).⁵⁰ These patients were judged to be at high risk of recurrence as they had tumors with one or more of the following characteristics: diameter >10 cm; mitotic index of greater than 10 mitoses per 50 high-power fields (HPF); tumor diameter >5 cm with greater than 5 mitoses per HPF; or tumor rupture before or at surgery. Patients had significantly greater RFS and overall survival (OS) (but not disease-specific survival) with 3 years of adjuvant

imatinib versus 1 year of treatment. At 5-year follow-up, the RFS and OS rates were 65.6% and 92.0% in the 3-year arm versus 47.9% and 81.7% in the 1-year arm ($p < 0.001$ and $p = 0.02$), respectively. Accordingly, the NCCN guidelines now recommend at least 3 years of adjuvant imatinib treatment for patients with KIT-positive GIST who are at high risk of recurrence based on tumor size, mitotic index, site, rupture, and completeness of surgery.⁵¹ Nevertheless, the optimal duration of adjuvant imatinib is still unknown. Two ongoing studies are currently addressing this question. The European Organization for Research and Treatment of Cancer (EORTC) 62024 trial (ClinicalTrials.gov identifier: NCT00103168) is a randomized, phase III study of 2 years of imatinib therapy in patients with GIST at intermediate or high risk of recurrence following resection, with a 5-year follow-up. PERSIST-5 (ClinicalTrials.gov identifier: NCT00867113) is a phase II trial evaluating up to 5 years of imatinib in patients at significant risk of GIST recurrence following complete resection. Results from these trials will provide additional information regarding the long-term use of adjuvant imatinib in patients with GIST.

CONCLUSION

Surgical resection has evolved as the mainstay of treatment for gastric GIST and LMS, while both endoscopic and surgical approaches are utilized for managing gastric carcinoids and lymphoma. When indicated, a range of approaches from endoscopic submucosal resection to open surgical resection can be utilized for removing benign gastric and malignant tumors. Although resection remains the best chance for cure, the advent of tyrosine kinase inhibitors, like imatinib, in combination with increasingly sensitive cross-sectional imaging technologies, and the growing number of minimally invasive surgical approaches have contributed to the evolution of treatment options and algorithms for the management of patients with nonadenomatous gastric tumors.

ACKNOWLEDGMENTS

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Laparoscopic resection for treatment of gastric cancer

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INTRODUCTION

Laparoscopy-assisted distal gastrectomy (LADG) with lymph node dissection for treatment of early gastric cancer was developed in 1991 in Japan.¹ Since then, efforts have been made to improve and evolve laparoscopic gastrectomy (LAG), because it is beneficial in terms of early recovery of gastrointestinal (GI) movements, reduced pain, and early hospital discharge.

Thus far, three options for laparoscopic surgical treatment of early gastric cancer with risk of lymph node metastasis have been developed: (1) laparoscopic wedge resection (LWR),² (2) intragastric mucosal resection,³ and (3) LAG. In the past two decades, development of new instruments such as a vessel sealing system, ultrasound coagulation devices, and circular or linear staplers have greatly contributed to the advancement of laparoscopic surgery.

Recently, in addition to early gastric cancer patients, LAG has also been attempted in advanced gastric cancer (AGC) cases owing to further development of the technique in several institutions.^{4,5} According to the Japan Society for Endoscopic Surgery (JSES), the number of LAG procedures increases every year. The development of this procedure has been slower in Western countries, compared with that in Japan and Korea.⁶ Although it is difficult to conduct a large-scale prospective study because of low incidence of gastric cancer in the Western countries, LAG may be gradually accepted as a standard treatment for gastric cancer in the future. Here we demonstrate the technique and discuss the current status of LAG as a minimally invasive approach for the treatment of gastric cancer.

CURRENT STATUS OF LAPAROSCOPIC GASTRECTOMY FOR GASTRIC CANCER

According to the recent Japanese Guidelines (4th edition), LAG is considered to be an optional treatment for stage I gastric cancer based on the results of several prospective studies in Japan using a sufficient sample size to investigate its benefits. Recently, Japanese surgeons have gradually expanded this to include treatment of advanced cancers with serosal tumor invasion or extragastric lymph node metastases and that of upper gastric cancer requiring total or proximal gastrectomy. However, the oncological feasibility of the laparoscopic approach for treatment of advanced cancer is still controversial, although evidence in support of it is increasing.

According to the 12th JSES national survey, the occurrence of intraoperative and postoperative complications in LADG was 1.3% and 9.1%, respectively. In contrast, the occurrence of intraoperative and postoperative complications in laparoscopy-assisted total gastrectomy (LATG) was 2.5% and 19.4%, respectively. Moreover, the incidence of operative complications in LADG is similar to that in open surgery, and anastomotic difficulties are still frequent in LAG for upper gastric cancer. To overcome these issues, several anastomotic procedures have been developed.⁷⁻⁹ In the future, it is important to establish standard and acceptable procedures of anastomosis after LATG or laparoscopy-assisted proximal gastrectomy.

Development of standard techniques and education and training systems is important to reduce the number of operative complications. Several training simulators and animal training centers have been developed to improve the

Table 60.1 Ongoing multicenter randomized prospective studies of LAG for AGC

Study	Design	Eligibility	Primary endpoint	Estimated enrollment
JLSSG0901	Randomized II/III (LADG vs. ODG)	MP/SS/SE N0–2 M0	P-II: Morbidity rate P-III: Relapse-free survival	P-II: 180, P-III: total 500
KLASS-02	III (LADG vs. ODG)	Advanced cancer	3-Year disease-free survival	1,050
CLASS-01	III (LADG vs. ODG)	Advanced cancer	3-Year disease-free survival	1,056

Abbreviations: CLASS, Chinese Laparoscopic Gastrointestinal Surgery Study Group; JLSSG, Japanese Laparoscopic Surgery Study Group; KLASS, Korean Laparoscopic Gastrointestinal Surgery Study Group; LADG, laparoscopy-assisted distal gastrectomy; ODG, open distal gastrectomy.

laparoscopic techniques. The accreditation system in Japan may contribute to the standardization of laparoscopic techniques and enhance surgical skills in the field of LAG.¹⁰ The Japanese qualification system must be repeatedly evaluated to ensure clinical relevance and educational importance for practicing surgeons.

TECHNIQUES OF LAPAROSCOPIC GASTRECTOMY WITH D2 LYMPH NODE DISSECTION

The extent of lymph node dissection in AGC cases remains controversial. In Asian countries, D2 lymph node dissection is routinely performed in AGC because it has the main advantages of prolonged survival and improved staging accuracy.^{11,12} Techniques of D2 lymph node dissection were recently developed for laparoscopic surgery and are being performed in several Asian institutions.^{13,14} It is necessary to establish safe techniques of infrapyloric and suprapancreatic lymph node dissection in LAG with D2 lymph node dissection for AGC cases (**Table 60.1**).

The surface of the head of the pancreas is carefully exposed during dissection of the infrapyloric lymph node, also known as the No. 6 lymph node. During dissection of the right gastroepiploic vein, care should be taken to avoid damaging the small vein running straight from the pancreas into its dorsal side (**Figure 60.1**). When dissecting the right gastroepiploic artery, it is important to identify the three branches of the anterosuperior pancreaticoduodenal vein and gastroduodenal artery first, and then confirm and process its root. The gastroduodenal artery should be checked from inside.

In suprapancreatic lymph node dissection, establishment of a better operation field is fundamental for complete and safe removal of the lymph nodes.^{15,16} In this surgical procedure, the pedicle of the left gastric artery and vein is carefully lifted, and the pancreas is moved downward to create a good operating field. The common hepatic artery is exposed from the bifurcation of the gastroduodenal artery toward the root of the left gastric artery, and the No. 8a and 12a lymph nodes and the right side of the No. 9 lymph nodes are dissected by exposing the right border of the celiac artery. Dissecting the connective tissue surrounding the nerve sheath around the common hepatic artery using coagulation shears is easy.

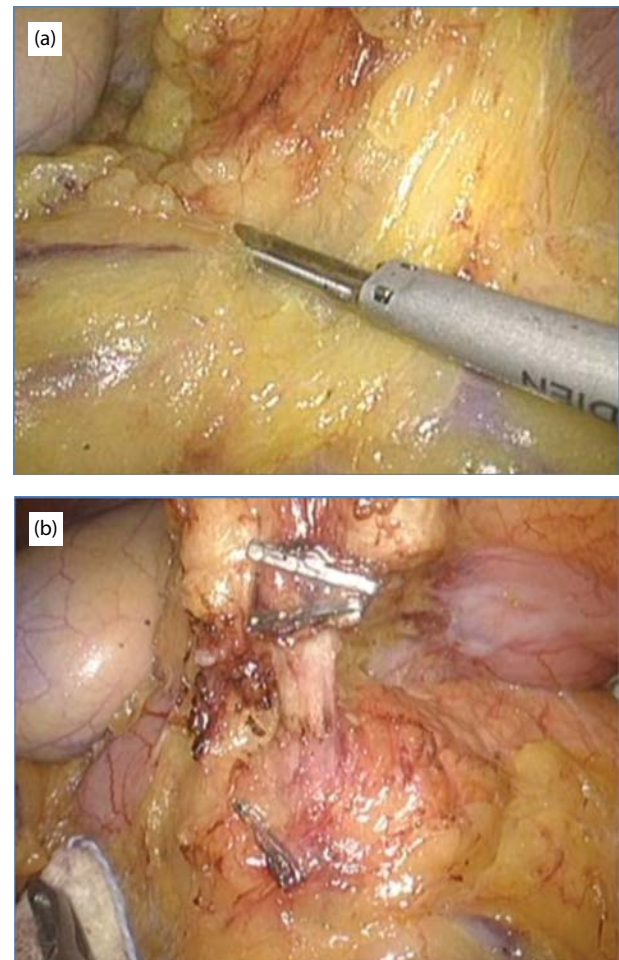


Figure 60.1 View after lymph node dissection infrapyloric area in obese patient. In general, the anatomy is unclear because of abundant fat tissue, rendering the manipulation of this tissue difficult (a). Care should be to avoid damaging the small vein to the pancreas (b).

Next, the left side of the celiac artery and the origin of the splenic artery are also exposed. The No. 11p and the left side of the No. 9 lymph nodes can be completely dissected using these steps (**Figure 60.2**). During suprapancreatic lymph node dissection, it is important to identify the anatomic landmarks before dissecting each lymph node.

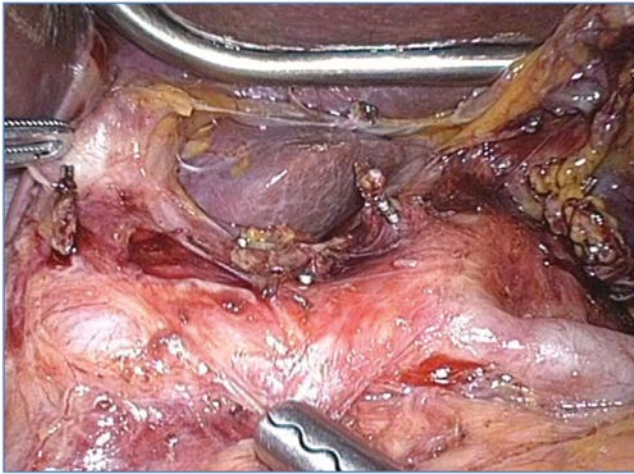


Figure 60.2 View after lymph node dissection around suprapancreatic area. Sharp dissection along the common hepatic and splenic arteries with complete removal to the soft tissue including suprapancreatic lymph nodes.

In LADG in obese patients, suprapancreatic lymph node dissection is sometimes difficult, because the borderline between the upper edge of the pancreas and fat tissue containing the lymph node is not visible because of oozing fat globules. Therefore, more technical development is necessary before obese patients can be adequately treated by LAG with D2 lymph node dissection.

TECHNIQUES OF ANASTOMOSIS AFTER LAPAROSCOPY-ASSISTED TOTAL GASTRECTOMY FOR UPPER GASTRIC CANCERS

Gastroduodenostomy or gastrojejunostomy after LADG have been safely performed using linear staplers or circular staplers, and this technique has gained worldwide popularity.¹⁷ In contrast, among the postoperative complications of LATG, the most common are anastomotic problems such as stenosis and leakage. Esophagojejunostomy after LATG may be performed using a circular stapler or linear stapler. Functional end-to-end anastomosis on the esophagojejunostomy is performed using a 45-mm endoscopic linear stapler. A small opening is created on the left side of the transected end of the esophagus just proximal to the staple line. Care should be taken to ensure that the opening exposes the esophageal mucosa to avoid creating a “false” lumen in the submucosal plane. The internal staple line is checked to ensure hemostasis. The joint esophagojejunal enterotomy is subsequently closed using a linear stapler (**Figure 60.3**). The same open method is used in end-to-side esophagojejunostomy with a circular stapler. However, it is sometimes difficult to insert the anvil head into the esophagus laparoscopically, and care should be taken to avoid injury of the esophageal stump.

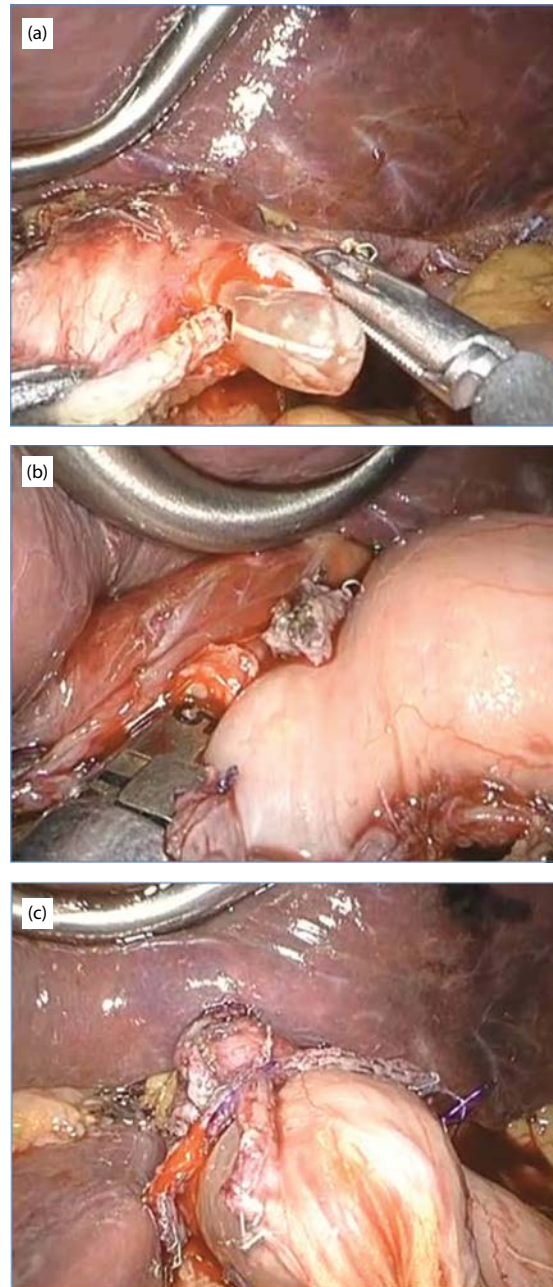


Figure 60.3 Reconstruction after LATG. (a) After cut of esophagus, a small hole was made at the left side of the end of the esophagus. (b) Functional end-to-end anastomosis on the esophagojejunostomy is performed using a 45-mm endoscopic linear stapler. (c) Entry hole was closed by a linear stapler.

Recently, a commercial transorally inserted anvil (OrVil; Covidien, Mansfield, Massachusetts) was developed. The usefulness and safety of this instrument during intracorporeal circular stapling esophagojejunostomy have been reported. It may be possible to reduce the risk of unexpected intraoperative complications (contamination by intestinal contents or esophageal injury) and the operating time.

CLINICAL TRIALS OF LAPAROSCOPIC GASTRECTOMY

The technical and oncological feasibilities of LAG have been evaluated worldwide. Several retrospective and prospective studies have been reported thus far. However, these studies may not provide sufficient evidence to obtain definite conclusions because the sample sizes used are small. Therefore, a multicenter randomized control trial (RCT) investigating the long-term outcome of LADG for gastric cancer is required. Thus far, multicenter trials have been conducted only in East Asia.

The Gastric Cancer Surgical Study Group of the Japan Clinical Oncology Group (JCOG) has conducted a multicenter phase II trial (JCOG0703) to evaluate the safety of LADG for clinical stage I gastric cancer.¹⁸ In addition, enrollment to a phase III trial (JCOG0912) comparing LADG and open distal gastrectomy (ODG) in terms of overall survival has already been completed, and the final results of this study are pending. The Korean Laparoscopic Gastrointestinal Surgery Study Group (KLASS) conducted a multicenter phase III trial comparing LADG with ODG for stage I gastric cancer. The enrollment of 1,400 patients was completed in 2010, and their final results are pending as well.

The Japanese Laparoscopic Surgery Study Group (JLSSG) started a phase II/III trial (JLSSG0901) of LADG for AGC to evaluate its technical and oncological feasibilities. In this study, surgery will be performed by credentialed surgeons who have a Board Certification by JSES to guarantee the quality of surgery. This RCT has a characteristic design, including definite inclusion criteria (limited to advanced cancer (MP/SS/SE) and control of lymph node dissection (limited to D2)). To control the quality of surgery, a central review of the surgical procedure using photography is performed for all enrolled patients. The KLASS from Korea and Chinese Laparoscopic Gastrointestinal Surgery Study Group

(CLASS) from China are also conducting phase III trials for AGC. The data collected will be beneficial for determining the role of LAG in treatment of both early and AGC.

CONCLUSION

Although there are several issues to be solved in terms of technical and oncological safety in laparoscopic surgery for gastric cancer, this technique will develop more and more owing to its advantages for patients with gastric cancer in the future.

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The laparoscopic placement of feeding tubes

JAISA OLASKY

INTRODUCTION

Laparoscopic enteric access has many potential utilities. In some cases it is a good option for palliation when an endoscopic or interventional radiology procedure is not the most feasible or safest option. In other cases, such as a postoperative gastric bypass patient, it may be needed for decompression of the biliopancreatic limb. Feeding tubes are also often placed with the laparoscopic technique during a minimally invasive gastrectomy, esophagectomy, or pancreatic debridement. Regardless of the indication, there are several feasible and safe methods for laparoscopic placement of a gastrostomy or jejunostomy tube.

GASTROSTOMY TUBES

Gastrostomy tubes are preferred over jejunostomy tubes whenever possible, because the larger lumen allows for bolus feeding. Patients who need long-term support are less restricted in their daily activities if they can use bolus feedings. In addition to convenience, bolus feeds avoid the need for an expensive tube feed pump. Gastrostomy tubes are also generally associated with fewer complications than jejunostomy tubes, as gastric feeding is thought to be more physiologic than direct intestinal feeding. However, in cases such as esophagectomy with gastric pull-up, gastric outlet obstruction, and severe pancreatitis, gastric feeds are not appropriate, except in cases when they are placed as a gastric vent and not used for feeding or medication administration.

There are several considerations that must be taken into account before proceeding with a gastrostomy tube. As mentioned, the disease process or past surgical history may alter the patient's anatomy, thus precluding placement of a tube in the stomach. In addition, imaging showing the transverse colon in an unfavorable position should alert the

surgeon to potential complications with a lower threshold for aborting the procedure.

Options for minimally invasive gastrostomy tubes include percutaneous endoscopic gastrostomy (PEG) tubes and surgical laparoscopic gastrostomy tubes. Prior to the incision, the patient is given intravenous antibiotics. There may also be efficacy in single-dose oral antibiotics prior to placement. Despite these measures, the rate of peristomal infections remains as high as 10%.^{1,2}

PEG tubes are considered to be the safest option for long-term feeding, as they are associated with the need for fewer additional interventions than nasogastric tubes and are less invasive than operative tubes. In a patient with less than 2 months predicted survival, there is no proven benefit over nasogastric tubes. There are, however, several scenarios in which PEG tubes are completely or relatively contraindicated. In a situation where the patient is already undergoing a laparoscopic procedure and does not have another indication for endoscopy, laparoscopic tube placement can be performed quickly and without adding much morbidity. PEG tubes are contraindicated when there are local issues that do not allow for endoscopy or passage of the placement tubing. The most common local mechanical issues are esophageal obstruction, large head and neck tumors, strictures, prior gastric surgery, or portal hypertension with large gastric varices. PEG is relatively contraindicated in situations where the direct approximation of the stomach to the abdominal wall is limited. This may occur with obesity, postoperative adhesions, prior laparotomy, ascites, prior colonic interposition, history of peritoneal dialysis, or carcinomatosis. Often, this can be predicted ahead of time based on physical exam or imaging. Some gastroenterologists and surgeons routinely obtain an abdominal computed tomography (CT) prior to PEG placement. If the colon appears to be in close approximation to the abdominal wall and directly anterior to the stomach, the regular PEG is not attempted, and a laparoscopic-assisted PEG, in which the surgeon mobilizes

the colon only, or a completely operative tube, is performed instead.³

If the patient does not meet criteria for PEG tube, and does meet criteria as listed above for gastrostomy tube, laparoscopic gastrostomy placement should be considered. The laparoscopic placement can be performed as quickly as open, even in patients with prior upper abdominal surgery, and usually with less postoperative pain.⁴

Setup for an isolated laparoscopic gastrostomy tube placement starts with the patient in supine position. The surgeon is on the patient's left and the assistant on the patient's right. A supraumbilical or infraumbilical camera port can be used, either with open Hasson access or first with Veress needle access. One to two 5-mm ports are added to triangulate toward the greater curve of the stomach. The two most common methods of fixation are balloon catheter placement with gastropexy and tube placement with T-fastener fixation.

Laparoscopic gastric tubes can be placed without need for specialized equipment by using a balloon catheter, such as a Foley or one taken from a PEG kit, with the gastropexy technique. Once the above-mentioned ports are placed, the patient is in reverse Trendelenburg position. The stomach is identified. Generally, there is no need to retract the liver; however, a Nathanson liver retractor can be used in the event of a very large left lobe of the liver. The surgeon identifies an area on the anterior greater curve of the stomach and places circumferential long sutures with the laparoscopic needle driver. If the surgeon prefers the EndoStitch device, he or she can use a 5-mm camera to avoid the need for a second larger trocar. Once each suture is placed, the needle is cut off and removed. The external location for the tube is chosen. The location is several centimeters below the left costal margin so that the patient can sit comfortably. The stomach must reach this area without any tension. A transfascial suture passer is used to bring each arm of the suture out, and the suture ends are held in place loosely with a snap. The laparoscopic shears or Maryland dissector with electrosurgical attachment is used to create a very small gastrostomy in the center of the sutures on the greater curve of the stomach. The instrument gently probes the opening to ensure that it is full thickness, but the hole must be kept small to avoid gastric leakage. A small stab incision is made with a knife at the external location for the tube, in the middle of the transfascial suture ends. The Foley or other balloon catheter is gently inserted through the stab incision and into the gastrostomy, and the balloon is inflated. The abdominal insufflation pressure is lowered, and the sutures and catheter are gently guided up to the abdominal wall and tied. The tube can be irrigated as a leak test. The tube is fixed in place externally with either a tube fixation tape device or sutures.

Surgeons who have the T-fastener device available can place a gastrostomy tube with this device for fixation. The T-fastener can be bought as a kit or assembled using a suture passer device. After the patient is positioned and trocars are placed in the same method as described for

a balloon tube, a nasogastric tube is insufflated to help visualize the stomach. If there is an esophageal lesion or other reason that a nasogastric tube cannot be placed, the stomach can be accessed with a small percutaneous needle under laparoscopic guidance and connected to insufflation that way. An external area is chosen for placement. As with the other technique, this site must be several centimeters away from the left costal margin for patient comfort and should be through the rectus muscle. On the stomach side, the site is chosen near the greater curve whenever possible. The insufflation pressure is kept at 5- to 7-mm Hg only. The 18-gauge needle attached to the device is placed through the abdominal wall and into the stomach. Once the device is in the stomach, the fastener is deployed. This is done four times circumferentially around the area of the intended tube placement. The four sutures are held with even pressure to bring the stomach up against the abdominal wall. The fastener deployment device is used again to enter the stomach in the center of the sutures, and the guidewire is passed through. Using a serial dilation technique, the tract is enlarged until an 18-French or larger balloon-tipped catheter can be inserted and the balloon inflated. If there is any concern about placement, intraoperative fluoroscopy can be used to confirm location or blue dye can be injected via nasogastric tube. The external bumper for the gastrostomy tube and the T-fasteners are tightened to secure the tube and stomach in place.

For both techniques, after the external fixation is complete, the abdomen is grossly inspected for bleeding or other injury, the pneumoperitoneum is released, and the umbilical fascia is closed either with suture passer or open suture, depending on the surgeon's preference.

JEJUNOSTOMY TUBES

Jejunostomy tubes are reserved for situations when a PEG tube and surgical gastrostomy tube are contraindicated, as previously described. In some cases, the patient has an existing gastrostomy tube that was placed before gastric emptying issues were identified. These patients are candidates for conversion to a G-J tube with endoscopy or interventional radiology. The jejunostomy tube is passed through the abdominal wall gastrostomy site and gently brought into the postpyloric space using instruments in the working channel of the endoscope. This can be difficult in a patient with a partial gastric outlet obstruction. In patients who do not have an existing gastrostomy tube, jejunostomy tubes can be placed with a simple open or minimally invasive procedure. In patients with need for distal feeding after major esophageal or gastric surgery, jejunostomy tubes have been shown to stay in place longer postoperatively with less accidental dislodgement than nasoenteric tubes, which allows the patient time to recover fully without the need for parenteral nutrition or multiple tube placements.⁵

Laparoscopic jejunostomy tubes can be placed as quickly as open and with the benefit of better identification of the ligament of Treitz (LOT) and therefore more proximal placement for better nutritional support than in the open procedure.⁶ Surgeons who prefer to Witzel the tube in place can perform laparoscopic identification and then make a small incision to do the open Witzel. Similar to the gastrostomy tube, the jejunostomy tube can be fixed in place with sutures or with the T-fastener device.

The initial patient setup for the laparoscopic jejunostomy tube is the same as previously described for the gastrostomy tube placement. Once the camera port has been established, two 5-mm ports are placed in the right side, one in the upper midclavicular area and one to the right and slightly superior to the umbilicus to establish triangulation toward the left mid-abdomen. The patient is placed in slight reverse Trendelenburg position. With atraumatic graspers, the transverse colon is elevated and the LOT is identified. Thirty centimeters distal to the LOT, an area of jejunum is selected that can easily reach the abdominal wall without tension. The bowel is insufflated via the nasogastric tube (NGT) and held up to the abdominal wall. At this point, the surgeon can proceed with placement using the T-fasteners or a sutured placement.⁷

The T-fastener device can be deployed in a similar fashion as previously described for gastrostomy tubes. It should be inserted into the antimesenteric side of the small bowel in a diamond shape. The proximal and distal small bowel should be checked for twisting or kinking. The T-fastener device is used to make a tract for a guidewire, and the introducer sheath is inserted with close care to ensure the device does not penetrate the posterior jejunal wall. Once in place, the 10-French jejunostomy tube is passed through the sheath, and the sheath is peeled back as the tube is slowly advanced for a length of 10–15 cm. The T-fasteners are tightened in place, and the J-tube is secured externally to the skin with several sutures. The area is examined and the abdomen desufflated. With this technique, there is no need to Witzel the tube.

Some surgeons prefer a sutured approach to avoid the risk of accidentally cutting the transfascial sutures with the sharp introducer as new sutures are placed. In the sutured approach, 3–0 nonabsorbable sutures are placed either with a free needle or with the EndoStitch device. Three seromuscular sutures are placed in a triangular fashion on the antimesenteric side. The assistant then holds the bowel up

with no tension, and the stitches are anchored to the internal abdominal wall. Either intracorporeal or extracorporeal knots can be tied to secure the sutures. At this point, the same technique for percutaneous access as previously described is used to introduce the jejunostomy tube and fix to the skin. Many surgeons place an additional intraabdominal stitch between the jejunum and the abdominal wall 3 cm distal to the entrance site. If the surgeon prefers to Witzel the tube, laparoscopic 00 or 000 silk sutures are placed to create the serosal tunnel.

Alternatively, one may opt to initially place only two of the three sutures of the triangle or the two T-fasteners farthest away from the camera first, then introduce the percutaneous jejunostomy tube, and then place the final sutures. In this scenario, the surgeon has direct visualization of the tube entering to ensure it is in the middle of the sutures.

POSTOPERATIVE CONSIDERATIONS

Tube feeds via gastrostomy or jejunostomy tube can be started at 24 hours. Medications can also be started through the gastrostomy tube after 24 hours. The complication rate for all of the procedures is low. In one study of 299 patients undergoing laparoscopic jejunostomy tube placement, the 30-day complication rate was 4% with the most common being tube dislodgment and clogged tubes. The most common late complication was jejunal-cutaneous fistula. With the low complication rate and many benefits, laparoscopic placement of feeding tubes can be an essential alternative to PEG placement or open placement with proper patient selection.

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SECTION VIII

Laparoscopic treatment of morbid obesity



John C. Gregory, *Obesity Surgery*, ca. 1966. US National Library of Medicine, Bethesda, MD.
(Image courtesy US National Library of Medicine and the Estate of John C. Gregory.)

This graphic poster from the 1960s shows a surgeon performing an operation on a bariatric patient. Quite characteristic of the esthetic of this period, the image has been pared down to what is absolutely necessary to convey a story. Instead of opting for a traditional realistic representation, as had been used in the depiction of surgeries in fine art for centuries, the artist has instead abstracted the scene by dividing it into monochromatic black-and-white fields using a few energetic lines. Fiery red, normally reserved for the blood emitted during an operation, has been used for the skin of the patient and doctor, drawing our eyes directly to the patient's face. The artist has also suggested the physicality of the patient by exaggerating the size of his head, seen from the front, which corresponds to that of his surgeon, depicted from the rear.

This poster was commissioned by Smith, Kline & French Laboratories, an American pharmaceutical company that is now part of GlaxoSmithKline in the United Kingdom. The illustrator of this poster, John C. Gregory (1913–2014), worked there as a graphic designer from 1956 to 1960. An artist, photographer, and designer, Gregory trained in a number of different media and styles. While stationed in Germany with the US Army in the early 1950s, he produced a number of drawings of everyday life, which transitioned into more graphic portraits like the one pictured. Following his time at the laboratory, Gregory moved on to become an acclaimed abstract painter.

The impact of obesity epidemic: Relationship between body mass index and 30-day mortality risk

SARA A. HENNESSY AND BRUCE D. SCHIRMER

OBESITY

Across the world approximately one in 25 people undergo a major operation in their lifetime¹ and any major postoperative complication can range from 3% to 21.9%.^{2,3} Obesity has long been considered a risk factor for adverse surgical outcomes due to preoperative comorbidities, technical challenges, metabolic disturbances, and inflammatory responses.

The rate of obesity is dramatically rising across the world, and the rise in obesity over the past 25 years in the United States has been dramatic. In 2014 over 1.9 billion adults were overweight and 600 million obese. Of all hospitalized patients, 46%–54% are overweight (body mass index [BMI] 25 kg/m²) and 32% are obese (BMI 30 kg/m²).^{4,5} As the prevalence of obesity rises in our society, so does the incidence of surgical patients that are obese.

When dealing with common surgical diseases in the obese patient, the basic principles of surgery apply. However, one must recognize that a definitive diagnosis may be delayed or difficult secondary to unreliability of physical examination, inaccuracy of the imaging technique, or the inability to perform the most appropriate imaging workup.

Obesity changes the normal physiologic response to the environment, stress, and adverse events by influencing and altering various organ systems. Obesity places patients at high risk for multiple acute and chronic medical conditions. More importantly, many patients may not have been diagnosed with these conditions at the time of their interaction with a surgeon. It is therefore imperative as the surgeon to perform a thorough preoperative clinical evaluation and be prepared for the types of comorbidities and complications common to the obese patient.

Definitions of obesity and epidemiology

Obesity is defined by the World Health Organization as abnormal or excessive fat accumulation in adipose tissue that can impair health. The classification of obesity is generally defined by BMI; however, it does not adequately reflect distribution of adipose tissue nor adipose tissue mass ([Table 62.1](#)). A BMI >30 kg/m² is associated with a sharp rise in morbidity and mortality.^{6,7} The risk of premature death doubles with a BMI >35 kg/m², and men are at greater risk of mortality than women for any given BMI.⁹

OBESITY-RELATED COMORBIDITIES

The impact of obesity on organ/physiologic systems places patients at high risk for developing one or more of the many medical illnesses associated with obesity ([Table 62.2](#)).

Cardiovascular disease

In obesity, cardiovascular physiology is altered; blood volume increases proportional to body surface area, which leads to increased preload and cardiac output.¹⁰ Eventually this leads to an increase in left heart diastolic filling and left ventricular hypertrophy¹¹ from increased preload and cardiac output.¹² When the heart can no longer respond to increased demands, congestive heart failure develops. During stress, increased CO is achieved by increasing heart rate rather than stroke volume.¹³ A general anesthetic is known to decrease cardiac index, this occurs to a greater degree in obese patients and persists postoperatively as compared to controls.¹⁴

Table 62.1 Classification of weight by BMI

BMI	Classification
BMI 25–29.9	Overweight
BMI 30–34.9	Class 1 obesity
BMI 35–39.9	Class 2 obesity
BMI >40	Class 3 obesity
BMI >50	Super-obese

Table 62.2 Medical diseases associated with morbid obesity

	Medical diseases
General	Increased mortality risk Poor wound healing
Cardiovascular	Hypertension Hyperlipidemia Hypercholesterolemia Atherosclerosis Coronary artery disease Congestive heart failure Venous stasis disease Cardiomyopathy Left ventricular hypertrophy
Pulmonary	Obstructive sleep apnea Obesity hypoventilation syndrome Asthma Pulmonary hypertension
Gastrointestinal	Nonalcoholic fatty liver disease Gastroesophageal reflux disease (GERD) Cholelithiasis
Renal	Stress urinary incontinence
Musculoskeletal	Osteoarthritis Gout Back pain
Neurologic	Stroke Pseudotumor cerebri Carpal tunnel
Metabolic/endocrine	Type 2 diabetes Metabolic syndrome Infertility Polycystic ovarian syndrome
Neoplastic	Cancer of the esophagus, stomach, liver, pancreas, kidney, gallbladder, colon, rectum, uterus, cervix, ovaries, breast, prostate; multiple myeloma; non-Hodg-kin lymphoma
Other	Depression Hypercoagulable state Proinflammatory state Intertrigo Lymphedema

There is an independent risk of coronary artery disease,¹⁵ stroke,¹⁶ myocardial infarction,¹⁷ and sudden death¹⁸ in obesity. Hypertension, which can lead to left ventricular hypertrophy, is associated with obesity as well.¹⁵ Cardiovascular disease is known to increase with rising BMI¹⁹ and is associated with a risk of heart failure.²⁰

Pulmonary disease

Respiratory physiology is altered in the obese with a decrease in compliance,^{21,22} total lung capacity, and functional residual capacity (FRC) with increased airway resistance.²³ As BMI increases, FRC decreases significantly,²⁴ leading to premature airway closure, atelectasis, and ventilation-perfusion mismatch all leading to hypoxemia.²⁵ In an attempt to compensate for the increased oxygen consumption and carbon dioxide production, obese patients have a higher minute ventilation (due to increased respiratory rate).

Alveolar hypoventilation leads to decreases in arterial oxygen saturation and increases in carbon dioxide that eventually lead to desensitization to hypercapnia and an increased dependence on hypoxic drive to maintain ventilation.²⁶ Based on the number of apneic events and clinical evaluation, patients are diagnosed with obstructive sleep apnea (OSA). Moderate to severe OSA has been linked to an increase in all-cause mortality and morbidity.²⁷ Of patients with OSA, approximately 10%–20% have obesity hypoventilation syndrome defined by hypercapnic respiratory failure and alveolar hypoventilation.²⁸ All of this leads to hypersomnolence, pulmonary hypertension, and heart and respiratory failure.

There is also a clear association between obesity and asthma, which may be mediated by gastroesophageal reflux disease (GERD).²⁹ The incidence of asthma in the obese is twice that of the normal population.³⁰

Gastrointestinal disease/nutrition

Cholelithiasis, GERD, *Helicobacter pylori*, and nonalcoholic steatohepatitis are gastrointestinal disorders that are commonly found in the obese population. Nonalcoholic steatohepatitis, which can lead to cirrhosis, may be an important factor in the development of insulin resistance in the morbidly obese.³¹ These disease processes could impact operative planning and postoperative complications.

Endocrinology

Insulin resistance and obesity are strongly associated, such that as body weight increases, the development of insulin resistance increases. Despite many potential mechanisms, the relationship is unclear but likely mediated by inflammatory events.

Metabolic syndrome defined as central obesity, reduced high-density lipoprotein (HDL) cholesterol, elevated triglycerides, elevated fasting glucose, and hypertension are associated with increased cardiovascular events and type 2 diabetes mellitus.³² Metabolic syndrome is also an independent predictor of postoperative complications.³³

OBESITY AND POSTOPERATIVE MORBIDITY

Respiratory complications

The evidence for postoperative respiratory complications and obesity is contradictory. Some studies have identified obesity as a risk factor for postoperative pneumonia, atelectasis, and pulmonary embolism,^{25,34–36} while other studies have found no association.^{37–39} This inconsistency is likely secondary to a lack of a consistent definition of obesity, population size, and multivariate analysis.

In 2007, Bamgbade and colleagues performed a retrospective review of over 7,000 patients from the National Surgical Quality Improvement Program database and found no difference in 48-hour postoperative ventilation, pneumonia, or unplanned intubation between obese and non-obese patients. However, they did find a higher prevalence of tracheal reintubation in morbidly obese patients.⁴⁰

Airway management can be difficult in obese patients.⁴¹ Obese patients are more difficult to ventilate via a mask, with a threefold increase when BMI is $>26 \text{ kg/m}^2$.⁴² While a high BMI does not predict difficulty with laryngoscopy or intubation, a high Mallampati score (>3) and a large neck circumference ($>40 \text{ cm}$) are good predictors of difficult intubation.^{43–45} The probability of difficult intubation increases from 5% at 40 cm to 35% at 60 cm neck circumference.⁴⁶

Venous thromboembolic complications

There is a strong association between obesity and venous thromboembolic (VTE) events.^{41,47–49} The incidence of deep venous thrombosis and pulmonary embolism ranges between 0.2% and 2.4%⁵⁰ in obese patients. VTE risk factors associated with obesity include decreased mobility, increased venous stasis, obesity hypoventilation syndrome, pulmonary hypertension, and potentially longer operative times.⁵¹

The Bariatric Outcomes Longitudinal Database monitored by the American Society for Metabolic and Bariatric Surgery demonstrated that 73% of VTE events occur after discharge.⁵¹ Despite many clinical practice guidelines recommending early postoperative and extended prophylaxis for this patient population, there has yet been any recommendations on dosage or duration.

Infectious complications

Numerous studies have demonstrated an association between obesity and infection. Choban and colleagues

retrospectively reviewed nosocomial infections and found an incidence of 2.8% in the obese and 4.3% in the severely obese as compared to a 0.5% incidence in the normal weight population.⁵² Obese patients have significantly higher occurrence of surgical site infections and urinary tract infections as compared to normal weight patients.^{40,53,54}

The rate of surgical site infections is significantly increased in obese patients,^{55–60} and the cause is likely multifactorial including diabetes, obesity-related immune dysfunction, decreased perioperative tissue oxygenation and perfusion, and inadequate antibiotic dosing.^{39,41,50,61–64} Surgical site infections are thought to be related to poor tissue oxygenation concentrations perioperatively secondary to tissue hypoperfusion.⁶³ The degree of thickness of the subcutaneous fat in abdominal incisions has been significantly associated with surgical site infections.⁵⁹ However, surgical site infections are significantly lower in laparoscopic procedures as compared to equivalent open procedures. DeMaria and colleagues found surgical site infections decreased from 10% to 1.1% with open to laparoscopic gastric bypasses.⁶⁵ Surgical site infection rates are similar between obese and nonobese patients for most laparoscopic procedures.

Insulin resistance and deranged glucose metabolism are associated with increased surgical site infections. These changes cause impaired macrophage function, angiogenic response, collagen accumulation, and growth factor.⁶⁶ However, strict perioperative glucose monitoring and control, although indicated, have not demonstrated benefit in noncardiac surgery.^{67,68}

Technical and intraoperative factors

There have been several differences found in the operating room in obese patients as compared to nonobese patients. Obese patients have significantly longer operative times despite the complexity of the operation.⁶⁹ Longer operations have been linked to rhabdomyolysis, and one particular study in patients undergoing bariatric surgery identified the risk of rhabdomyolysis as high as 22.7%. However, more commonly, the rate usually ranges from 1% to 5%.⁷⁰ Given the risk, special care is required in patient positioning on the operating room table to minimize patient slippage and muscle trauma. Obesity has been demonstrated to be a risk factor for conversion from laparoscopic to open procedures,⁷¹ however, even this is controversial as much of this depends on surgeon experience and technical ability.

Bamgbade and colleagues found in a large retrospective review of the National Surgery Quality Improvement Program database that obese patients had a significantly higher rate of peripheral nerve injury. They concluded that the higher incidence was likely secondary to prolonged surgery and immobilization with significant pressure on vulnerable peripheral nerves by the obese body. The peripheral nerves at highest risk were the ulnar nerve and peroneal nerves which should be protected by pressure relief devices.

In addition, in obese patients, upper and lower limb abduction should be minimized to avoid traction injury.⁴⁰

In conclusion, there is an overall paucity of large extensive studies on the influence of BMI or obesity on surgical outcomes. In addition, the studies that do exist are often contradictory. Surgical site infections are the only postoperative complication that has been consistently demonstrated to be higher in obese surgical patients. Some studies have demonstrated severe postoperative complications, while others have failed to demonstrate any significant risk of mortality or morbidity. Most studies are limited by lack of statistical power, small sample sizes, single institution, retrospective design, lack of short- and long-term follow-up, types of procedures, definitions used, and types of outcomes studied.

OBESITY AND POSTOPERATIVE MORTALITY

The majority of studies have failed to find an association between obesity and postoperative mortality.^{39,40,72-74} Mullen and colleagues performed a large multi-institutional prospective study through the National Surgical Quality Improvement Program in over 2,000 patients undergoing intra-abdominal surgery. Obesity (BMI >30 kg/m²) was not identified as a risk factor for mortality.³⁹ These results were similar to other groups who studied the influence of BMI on postoperative outcomes. There was no association identified between BMI and mortality in esophagectomies, hepatic resections, pancreatic resection, colorectal surgery, or cardiac surgery.^{39,40,72-74}

THE OBESITY PARADOX

Mullen and colleagues performed a prospective, multi-institutional study performed on patients undergoing non-bariatric surgery. In this study, they described “the obesity paradox,” which describes a J-shaped relationship between 30-day mortality and BMI. Patients who were overweight (BMI 25–30) and moderately obese (BMI 35–40) had odds ratios of 0.85 and 0.73, respectively, lower as a rate of adjusted mortality compared to normal weight patients. The highest rates of adjusted mortality were found in underweight patients (BMI <18.5) with an odds ratio of 1.35 and those with morbid obesity (BMI >40) with an odds ratio of 1.04. They also demonstrated a progressive increase in morbidity with increasing BMI; this was mainly composed of surgical site infections.⁶⁹

The physiologic mechanism behind the “obesity paradox” can be explained by the integration of metabolic regulation and the immune response. A low-grade chronic inflammatory state is present during obesity with an upregulation of adipokines and cytokines.⁷⁵ This inflammatory state triggers the same signaling pathways that are triggered during a response to injury and tissue repair.⁷⁶ Therefore, in the obese state, with a sufficient nutritional reserve and primed metabolic and inflammatory state, the

obese patient is prepared to mount an appropriate immune response to the stress of surgery.

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Laparoscopic adjustable gastric banding

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INTRODUCTION

Laparoscopic adjustable gastric banding (LAGB) is a restrictive bariatric operation that involves the placement of an implantable device around the upper part of the stomach. This device is unique in the fact that it is adjustable. The operation is quite appealing, because it does not involve any resecting or stapling of gastrointestinal tissues. Nevertheless, the weight loss resulting from the procedure is absolutely dependent on both a patient's ability to follow up and a surgeon's availability for such follow-up. Today's LAGB procedure involves the implantation of a silicone ring with a soft inflatable balloon inside. This balloon is connected, via hollow tubing, to a subcutaneous access port. The port is accessed via a noncoring needle.

HISTORY OF GASTRIC BANDING

Restrictive operations are appealing due to the lack of the vitamin and nutritional deficiencies experienced with the malabsorptive procedures. Partitioning of the stomach has been performed in many different procedures to make a far smaller reservoir to hold food prior to its antegrade propagation through the gastrointestinal tract. Such a partition will lead to decreased hunger and early satiety. Success has been seen in the restrictive gastric bypass and the vertical sleeve gastrectomy. Attempts had been made in a nonanastomotic restriction operation called the vertical banded gastroplasty (VBG). This operation leads to weight loss; however, it had its own pitfalls including recannulation across staple lines, fistulas, and pouch failure.

In 1985, Hallberg and Forsell implanted adjustable gastric bands in Sweden. This resulted in an early prototype known as the Swedish adjustable gastric band. In 1986, Kuzmak of the United States implanted inflatable gastric bands with smaller inner balloons operating under a higher

pressure and lower volume system than the Swedish bands.¹ Belachew from Belgium described successfully performing this procedure laparoscopically in 1993.²

There has been an evolution in the way the procedure itself has been performed. This has ultimately led to a decrease in postoperative complications. Early reports described a perigastric technique of LAGB placement. Originally, a window was created along the lesser curvature of the stomach (about 3 cm below the gastroesophageal junction). This dissection was carried out superior to the first short gastric vessel. The band was placed around the stomach through this tunnel. A 15- to 30-cc gastric pouch was created above the band. By entering into the lesser sac posterior to the stomach, a set-ting was created whereby the posterior gastric wall could slip through the band causing a posterior gastric prolapse. Symptoms related to this included pain, dysphagia, vomiting, and reflux. This complication was initially reported in nearly 23% of LAGB procedures.³ Additional concerns were that larger pouches could result in pouch dilation, and a close dissection of the posterior wall of the stomach could lead to deserosalization of the stomach.⁴ Therefore, this paved the way to the development of the *pars flaccida* technique—the LAGB placement technique described here and in use today. This technique resulted in far fewer postoperative complications (including gastric prolapse) without compromising the weight loss attained by the gastric band.⁵⁻⁷

ANATOMY

There are particular anatomical landmarks that must be understood prior to performing the LAGB procedure. The esophagus traverses through the mediastinum and enters into the abdominal cavity via the esophageal hiatus of the diaphragm at the level of the 10th thoracic vertebrae. This hiatus consists of a left muscular portion (the left crus) and

a right muscular portion (the right crus). The right portion scoops around the esophagus. Behind the gastroesophageal junction is a point where the left and right crus seem to come together. This is often referred to as the “confluence of the crura.” Without any hiatal or paraesophageal hernias, under normal circumstances, there will be approximately 2–3 cm of intra-abdominal esophagus. Through the esophageal hiatus passes not only the esophagus itself, but also neurovascular tissue, in particular, the anterior and posterior vagus nerves. It is important during this procedure to be mindful of these structures—as one does not want to encounter bleeding, cause devascularization, or compromise vagal input to ensure normal gastrointestinal functionality. Generally, there will be an anterior fat pad overlying the area of the gastroesophageal junction. The size of this fat pad is often directly correlative to the level of obesity of the patient. In this region is the angle of His. This is the angle that exists in front of the left diaphragmatic crura between the abdominal esophagus and the fundus of the stomach.

The upper portion of the gastric fundus is attached to the left part of the diaphragm (the left crus) by the gastrophrenic ligament. The gastrosplenic ligament attaches the greater curvature and fundus to the splenic hilum. The short gastric vessels are in this tissue. The midportion of the stomach, along the lesser curvature, is attached to the liver by the hepatogastric ligament. There is a clear area of this ligament overlying the caudate lobe of the liver. This is often referred to as the *pars flaccida*. The lesser sac is an isolated portion of the peritoneal cavity that consists of a peritoneal lined potential space that is posterior to the stomach and anterior to the posterior abdominal structures (i.e., pancreas). Superiorly, this sac extends up just to a recess posterior to the caudate lobe of the liver. This potential space is situated a few centimeters inferior to the confluence of the crura at the esophageal hiatus.

OPERATIVE TECHNIQUE

Instrumentation and setup

Prior to starting to perform the LAGB procedure, one should make sure adequate instruments are available. First, the use of extra-long instruments (>43 cm) facilitates the operation due to the fact that patients may be larger due to the nature of bariatric surgery and due to considerable distance between comfortably placed ports and the gastroesophageal junction. Furthermore, a Nathanson liver retractor (Cook, Bloomington, Indiana) is our chosen form of liver retraction due to ease of visualization.

The patient is positioned supine on the operating room table with both arms extended and both legs together. Padding of the extremities is extremely important. It is suggested that the anesthesiologist place an orogastric tube for gastric decompression. This tube is removed once adequate decompression is confirmed prior to beginning

the dissection. The surgeon should stand to the patient's right side, and the assistant should stand on the patient's left side.

Port placement

A five-port technique is suggested. The abdomen is entered using an optical 12-mm trocar in the left midaxillary line about two to three fingerbreadths below the costal margin. Along this same axis, two 5-mm ports are placed—one in the right midaxillary line and one in the left midclavicular line. In the midline, between the two 5-mm trocars, a 15-mm trocar is placed. Finally, an entry point is made using a 5-mm trocar just below the xiphoid process. Then, this trocar is removed, and the Nathanson liver retractor is carefully placed. This is a fixed, curved retractor that is attached to a self-retaining mechanical arm. The curve of the retractor should support the heaviest portion of the middle of the left lobe of the liver. This allows perfect visualization of the gastroesophageal junction permitting ease of dissection. The left-sided 12-mm trocar is used for the camera. The use of a 30° laparoscope is necessary for proper visualization and safe dissection.

Angle of His dissection

To expose the angle of His, the greater curvature fat must be retracted caudally. To safely do this, and to minimize bleeding, it is suggested that a long closed grasper is placed through the left-sided 5-mm port along the greater curvature fat/omentum just above where the short gastric vessels begin. This should be done in a sweeping motion assuring there is no grabbing, as grabbing this tissue will surely result in bleeding. The handle of the grasper, to be held by the assistant, should eventually be at a right angle with the abdominal wall allowing gentle caudal retraction of the fundus, retraction of the fat, and adequate visualization of the angle of His. Another long grasper is placed through the right-sided 5-mm port, and the fundus is gently held and retracted caudally to help with visualization of the angle of His. Dissection of peritoneal tissue is performed with a laparoscopic shear or hook electrocautery. Such dissection starts just to the left of the gastroesophageal junction but above the first short gastric vessel. Gentle dissection should free all peritoneal attachments from the upper fundus and angle of His from the underlying diaphragm/left crus. A small incision is made just to the left of the gastroesophageal junction, through the gastrophrenic ligament, to allow a small window into the space just behind the gastroesophageal junction. (**Figure 63.1**). It is important to note that all this is being created cephalad to the top of the lesser sac.

There are fat pads at locations around the upper part of the stomach and the gastroesophageal junction. Most predictably, there is a superficial anterior fat pad around the angle of His. With the new bands used today, it is not always necessary

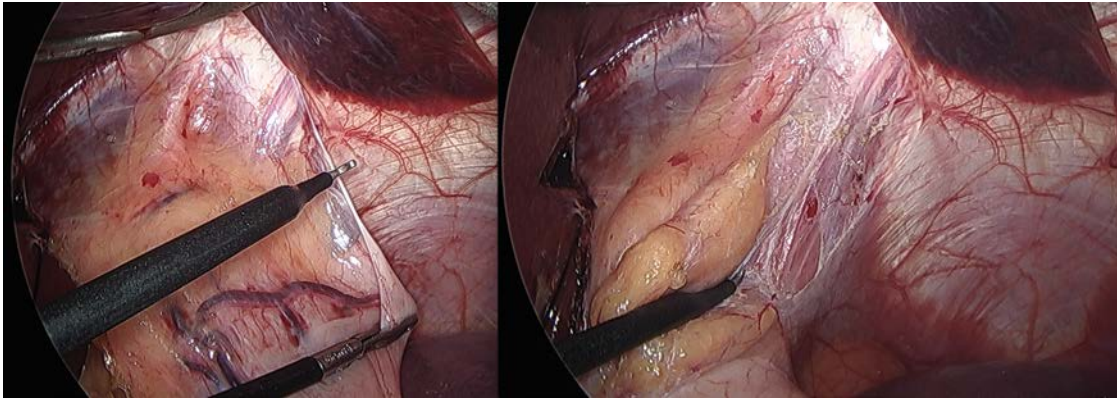


Figure 63.1 Angle of His dissection.

to remove these fat pads. It is suggested to remove them if they impede proper visualization for dissection or if they make the band appear “too tight” around the stomach. In these cases, care should be taken to remove the fat pads hemostatically without injuring the underlying gastric serosa. This involves gentle retraction of the fat pad and removal with either hook electrocautery or an ultrasonic scalpel.

Pars flaccida dissection

The lesser omentum is divided at the *pars flaccida* (clear area) between the lesser curvature of the stomach and the liver, overlying the caudate lobe of the liver. With medial retraction of the lesser curvature fat, the right crus of the diaphragm is identified. It is suggested to gently lift the caudate lobe of the liver to decipher the inferior vena cava from the diaphragmatic crura. There is a point where this right crus of the

diaphragm disappears into retroperitoneal fat. This is near the level of the confluence of the crura. Here, peritoneum just medial to the right crus is incised with electrocautery. A long grasper is passed through the right 5-mm port and gently passes to this area. Through the window made in the retroperitoneal fat, this grasper should gently pass behind the gastroesophageal junction to come out at the previously dissected angle of His. It is of utmost importance that no resistance be sensed during this passage of the instrument. This dissection is often described as feeling as if a “hot knife is going through butter.” Any resistance may mean the following—the tunnel is too high along the right crus and pushing against the left crus or the tunnel is too anterior and abutting the posterior of the esophagus or the stomach. Once the end of the grasper is visualized safely beyond the angle of His, it is ready to grasp the gastric band ([Figure 63.2](#), top images).

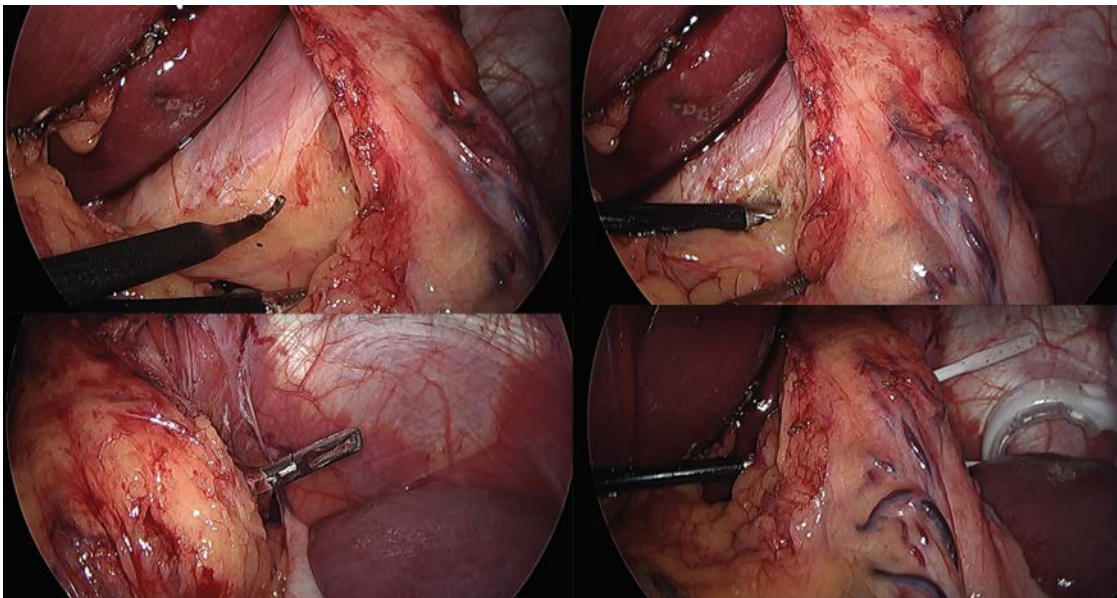


Figure 63.2 *Pars flaccida* dissection.

Introduction of the gastric band

The band is introduced into the abdominal cavity through the 15-mm port. The band should be grasped at its buckle, with the balloon of the band flush with the shaft of the instrument. This is to ensure there will be no damage to the device. After the band is safely in the patient's left upper quadrant, the remainder of the tubing is advanced into the abdominal cavity as well, all under direct vision to ensure safety. Once inside the abdomen, the end of the tubing is retrieved with the grasper (at the area of the angle of His). At this point, the right-handed grasper is gently pulled out of the body (grasping the band tubing), pulling the band itself around the stomach (**Figure 63.2**, bottom images). By pulling the tubing out from the retrogastric tunnel, the band will position itself around the stomach, approximately 2 cm below the gastroesophageal junction. Next, the end of the tubing is passed through the opening on the band to lock it into place (**Figure 63.3**, left). We usually like to assure ourselves that the band is not too tight around the stomach—the tip of a 5-mm instrument should easily pass between the band's balloon and the stomach. Furthermore, the band should be able to gently rotate freely. If this appears too tight, some extra perigastric fat may need to be dissected off of the stomach. This is less of an issue with the currently used larger models of the gastric band.

Anterior fundoplication

With the *pars flaccida* technique, posterior retroperitoneal attachments secure the band posterior to the stomach. This helps avoid the previously seen issue of posterior gastric prolapse experienced with the older perigastric dissection technique. Nevertheless, it is important to take proper steps to avoid an anterior prolapse or “band slippage.” To secure the band anteriorly, gastrogastic suturing is performed. The fundus below the band is sutured to the upper gastric pouch. This can be done in a running or interrupted manner (surgeon preference). We advise the use of a 2–0 permanent suture for this step. This plication need not be too tight or too close to the buckle of the gastric band (**Figure 63.3**, right). These

steps help prevent band erosion. It is suggested to start as far left along the great curvature as possible in order to allow an adequately long fundoplication. Points to be careful of are as follows: avoid puncturing the balloon of the band with the needle, which would result in failure to inflate the band, and avoid incorporating the esophagus in the upper gastric pouch bites, as this will force the band to sit too high (possibly around the esophagus), not allowing proper restriction.

Access port placement

After the band is secured in place, the end of the tubing is grasped and pulled out of the body via the 15-mm trocar. The tab at the end of the tubing is cut off and attached to the access port. At this point, the trocars and the liver retractor can be removed under direct vision. The first step in securing the port to the patient is to dissect through all subcutaneous tissue to expose the anterior sheath 2–3 cm to the patient's right from the trocar entry site (from where the tubing exits the body). Narrow Deaver retractors are extremely helpful to do this, as it can be challenging in the bariatric patient population. Then, at the site 2–3 cm from the fascial defect, a small cut is made in the anterior sheath until muscle is exposed. This allows assurance that all bites will include the anterior sheath. Then, 0 Ethibond sutures are used. Bites are taken at four points through the fascia, and the needles are cut off. Then, the sutures are threaded through the small holes in the port. All four sutures are securely tied down, assuring the port is flat and secure against the anterior sheath. Then, the excess tubing is gently advanced through the fascia defect into the abdominal cavity (**Figure 63.4**). Some surgeons close the fascial defect (from the 15-mm port) with a 0 Vicryl stitch, being careful not to nick or compress the band tubing. Nevertheless, many bariatric surgeons feel this step is not necessary. The skin incisions are closed using a 4–0 Monocryl subcuticular stitch.

POSTOPERATIVE CARE

The patient should be sent to the recovery room. If the patient had an uneventful anesthetic experience, he or she

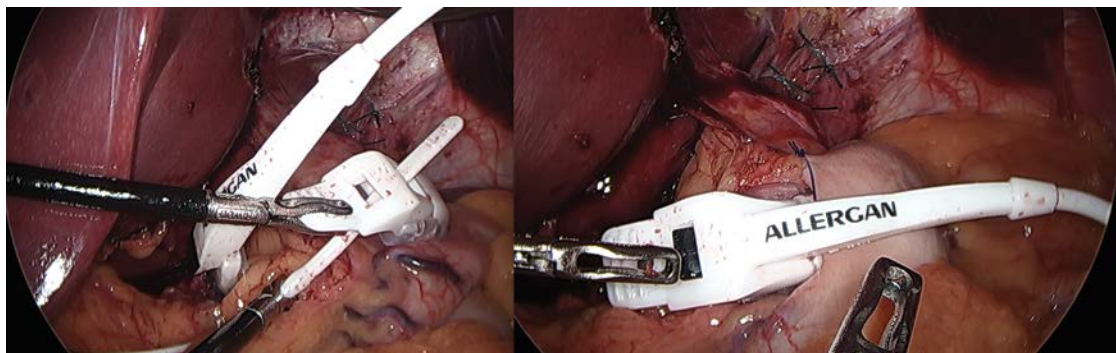


Figure 63.3 Gastric band locked and gastric plication.

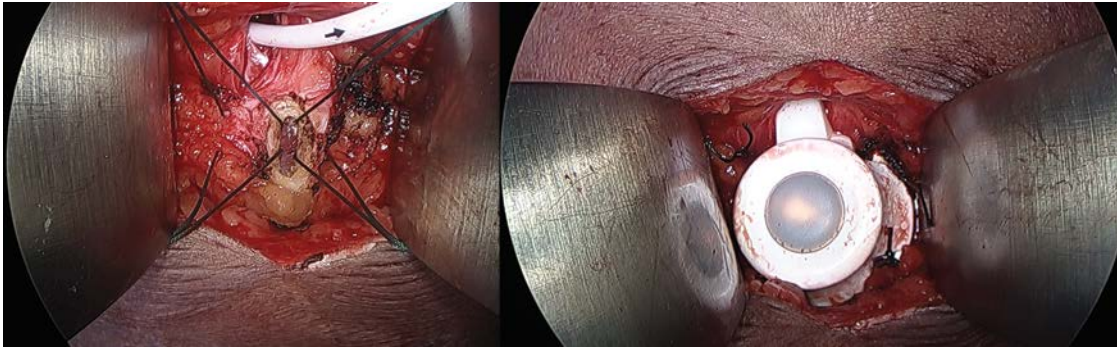


Figure 63.4 Access port placement.

wakes up and is immediately started on liquids and ice chips. Once the patient can tolerate a drink of water, can ambulate without difficulty, and can urinate, he or she is discharged home. In 1 week, we perform routine limited upper gastrointestinal studies (“esophagograms”) on our patients to confirm appropriate band position and appropriate flow of contrast distal to the band (**Figure 63.6**, left).

A NOTE ON HIATAL HERNIAS

During the dissection of the angle of His, it is easy to note if there is a crural defect or hiatal hernia. It is highly suggested that these should be aggressively repaired. If a sliding hiatal hernia is noted, this should be repaired with full mobilization of the distal esophagus, assurance of complete reduction of the hernia, and assurance of the ability of the gastroesophageal junction to sit in the abdominal cavity (with 2–3 cm of intra-abdominal esophagus) without any tension. During the posterior mobilization of the esophagus, it is important to be cranial to the lesser sac to avoid any problems of posterior gastric prolapse with band placement. When a sliding hiatal hernia is present, the crural repair is best performed with posterior nonabsorbable figure-of-eight sutures.

In many cases, there is not a sliding hernia, yet a weakness or “dimple” is noted in the anterior part of the crura. In these cases, where a complete esophageal dissection is not necessary, we suggest performing a “cruroplasty.” During the dissection of the angle of His, the anterior esophagus is mobilized, and the two pillars of the crura are isolated. If the gastroesophageal junction is within the abdominal cavity, this anterior laxity can be repaired with an anterior repair consisting of a figure-of-eight nonabsorbable suture (**Figure 63.5**).

It has been shown that aggressive crural repairs (posterior or anterior) can decrease band-related complications including gastric prolapse (“band slippage”), pouch dilation, and intractable reflux. Such aggressive crural repairs can decrease the number of reoperations.^{8,9} Also, for patients with just a laxity at the crura, it has been shown that anterior versus posterior crural repairs had no statistical difference in complications or recurrences.¹⁰

MANAGING THE GASTRIC BAND PATIENT

The weight loss experienced from LAGB surgery is related not simply to the operation itself, yet it is a result of a series of systematic band adjustments bringing a patient to his or her own unique level of “restriction.” The endpoint is to allow the

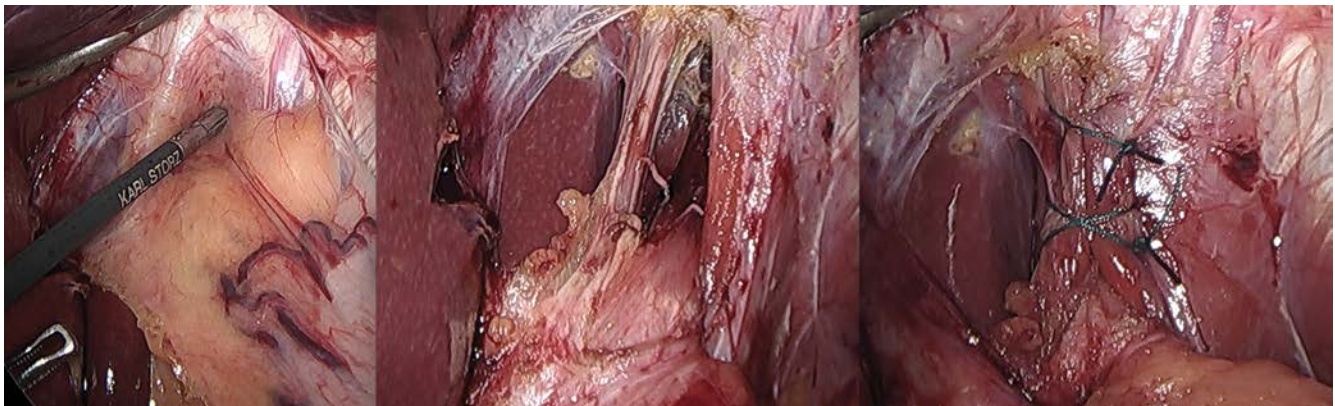


Figure 63.5 Hiatal hernias/cruropepy.

patient to reach an equilibrium where he or she will have a lack of baseline hunger, will feel satiety with a small portion of well-masticated food, yet will not be experiencing vomiting or reflux. Patient behavior is a key component to this. Patient education is key to the success of this bariatric procedure. Food must be chewed for 30 seconds, and the patient must dramatically slow down their eating. Furthermore, dry, doughy foods (i.e., doughy breads, well-done beef, and white meat chicken) should be avoided. Also, a patient should not drink while eating as this can affect proper transit of food from the gastric pouch, through the band, into the distal stomach.

Band adjustments begin 4 weeks after the operation. This provides enough time for any postoperative swelling to pass. We often suggest patients follow up monthly for the first 18–24 months after surgery. Adjustments are performed when the patient describes “feeling hungry,” when the patient is not satisfied with a smaller meal, when the patient feels he or she is eating too much or too often, or when there is less than 0.5- to 1-kg weight loss per week.

If a patient describes symptoms such as an inability to eat most foods, nighttime cough, gastroesophageal reflux, or emesis, the patient is likely too “tight.” At these instances, it is necessary to remove some fluid from the band. A patient who remains too “tight” is at risk of gastric prolapse (“band slippage”), pouch dilation, esophagitis, and aspiration.

Calibrating the gastric band

Adjustments are done in the office. Some surgeons perform fluoroscopic-guided band calibrations. An erect patient drinks barium, and in real time, fluoroscopy is performed. The band is slowly filled with saline solution until the fluoroscopy shows there is adequate “restriction” (or slow down at the band) without reflux or obstruction. This technique requires an in-office x-ray machine and can be time consuming. We advocate systematic in-office adjustments based on the patient’s clinical status.

To perform an adjustment, the patient is positioned supine on an examination table. The port is located by palpation. The skin above the port is treated with an alcohol swab. A syringe is prepared and filled with sterile 0.9% saline solution. A Huber needle is used to access the port, as it does not core out the port and decreases the chance of causing a leak in the system. The port is accessed with the needle percutaneously, approached from the right lateral aspect of the port. This also decreases the risk of any puncture to the band tubing. If a port cannot be accessed by palpation, fluoroscopy or ultrasound can help localize the device. Once the needle is in the port chamber, saline is instilled into the device. It is often helpful to aspirate some of the injected saline to assure the port has been accessed correctly.

Titrating the band and band choice

The bands most commonly used include the Lap Band (Apollo Endosurgery, Austin, Texas) and the Realize Band

(Ethicon Endosurgery, Cincinnati, Ohio). There are two sizes of Lap Band—the AP-L system (large) and the AP-S system (standard). The Realize band and the AP-S hold approximately 10 cc of fluid, and the AP-L system holds approximately 14 cc of fluid. Band type is based on surgeon preference. Band size (AP-L versus AP-S) is based on the amount of perigastric fat, size of the fat pads, and girth of the gastric tissue. Band choice is often clinically determined intraoperatively. Nevertheless, the band titrations are relatively standardized. At initial placement approximately 3–4 cc are instilled. This is not only to start to fill the band, but to prime the system (filling up the tubing with saline). At the second fill, 1–2 cc are added to the band. Subsequently, 0.5–1 cc are instilled on a monthly basis depending on the clinical scenario. If a patient is losing 4 pounds or more a month with good “restriction” (early satiety and portion control) in the setting of avoidance of reflux and emesis, a fill is not necessary. Should the patient be experiencing negative symptoms (nighttime cough, reflux, or emesis) fluid should be removed. It is suggested that the patients attempt to drink some water prior to leaving the office to assure there is no obstruction. Furthermore, due to the potential temporary swelling in the area around the band after an adjustment, it is often advocated that the patient remain on a liquid diet for the first 2 days after the adjustment.

After the initial months of band calibration, patients will find themselves at a point where they are comfortable in terms of their restriction. Once-monthly follow-up is no longer required; it is suggested the patients have follow-up every 6 months to a year. Furthermore, it is always suggested that the patients undergo an annual esophagogram to assess for any change in position of the band, dilation of the esophagus, pouch dilation, or port migration. On a normal esophagogram, the band should sit at a 45° angle to the esophagus with no apparent obstruction of contrast and no excessive stomach cephalad to the band.

COMPLICATIONS

No bariatric operation is without its potential complications. The benefit of gastric banding is that the complication of a perforation of viscera is exceedingly low. Furthermore, by avoiding staple lines and anastomoses, there is obviously no risk of leak or dehiscence. Nevertheless, there are device-related complications. Most of these are fixable with an outpatient procedure.

Gastric band erosion

Probably one of the most concerning complications is erosion of the gastric band through the wall of the stomach. This complication is exceedingly rare. In such cases, the band erodes through the wall of the stomach and eventually becomes partially (or eventually completely) intraluminal. There are no acute signs of symptoms of illness. This

complication is believed to be a result of serosal injury during placement of the device or due to the fundoplication being made too tight near the buckle of the band. Patients realize there is an issue often due to a lack of weight loss or a lack of early satiety related to failure of outward restriction of the band against the wall of the stomach. Furthermore, due to the intraluminal presence of the device, bacteria often migrate along the tubing to the gastric band port. In such situations, the herald sign of band erosion is a late port site infection. Any patient with a late port site infection should undergo endoscopy to assess for band erosion. In fact, the definitive diagnosis is made with an upper endoscopy showing intraluminal presence of all or part of the gastric band. In cases of band erosion, it is imperative to remove the gastric band and port. More often than not, the gastrostomy has healed and sealed over by the time of diagnosis. However, if a gastrostomy is found, it is best to close it primarily with absorbable sutures and patch it with a piece of omentum. Also, in such cases, we suggest temporary postoperative drainage of the area to minimize contamination.

Gastric prolapse or "slippage"

Anterior gastric prolapse is often described as a "slip." In this situation, a portion of the stomach abnormally migrates through the band. Most commonly, this involves the greater curvature, the most mobile part of the stomach. Failure of the gastro-gastro fundoplication can result in this anterior gastric prolapse. In most cases, the sutures fail as a result of patient noncompliance, such as overeating to the point of vomiting. As a result of an anterior prolapse, a preferential pathway for food is established, further enlarging the herniation. Symptoms associated with the anterior gastric prolapse include acid reflux (especially nocturnal), nausea, vomiting, and bloating. Paradoxically, the patients often complain of weight gain because a much larger gastric pouch is present and more food can be ingested and tolerated.

Before the *pars flaccida* technique of band placement, the perigastric technique involved the formation of a larger and lower retrogastric tunnel. This dissection often resulted in an erroneous entry into the lesser sac. In these cases, the posterior wall of the stomach, by similar mechanisms as above, herniated through the band creating a similar constellation of symptoms. Nevertheless, with the modern method of band placement, this complication is nearly nonexistent.

When a gastric prolapse occurs, the patient often comes in complaining of reflux, solid food intolerance, nausea, and vomiting. Definitive diagnosis of band slippage is made with an esophagogram (Figure 63.6, right). There is a change in the angle of the band, as it loses its normal diagonal orientation and becomes horizontal (sometimes resulting in a 90° or greater angle to the esophagus). Furthermore, excessive stomach is seen cephalad to the band. In more severe cases, this is also associated with a failure of oral contrast to pass distal to the band showing a partial or complete obstruction. In such cases, the first thing to do is remove all of the fluid from the band to help alleviate the symptoms and relieve any possible obstruction. Then, the band often needs to be repositioned or replaced with a laparoscopic revision procedure.

Gastric band slippage becomes an emergent situation when the patient reports pain out of proportion to physical exam. Associated concerning findings include, yet are not limited to, leukocytosis, tachycardia, and peritonitis. In these cases, the concern is that the patient has experienced gastric prolapse, and due to compression of the arteries or lack of venous outflow, the gastric pouch that has herniated has become ischemic or necrotic (Figure 63.7). In any case of a patient with gastric prolapse and pain as described, diagnostic laparoscopy is imperative. By relieving the obstruction, one can alleviate the ischemia. In cases where ischemia has advanced to gastric necrosis, the band must be removed and any necrotic stomach needs to be excised. If the surgeon is comfortable, this can be done laparoscopically. One can

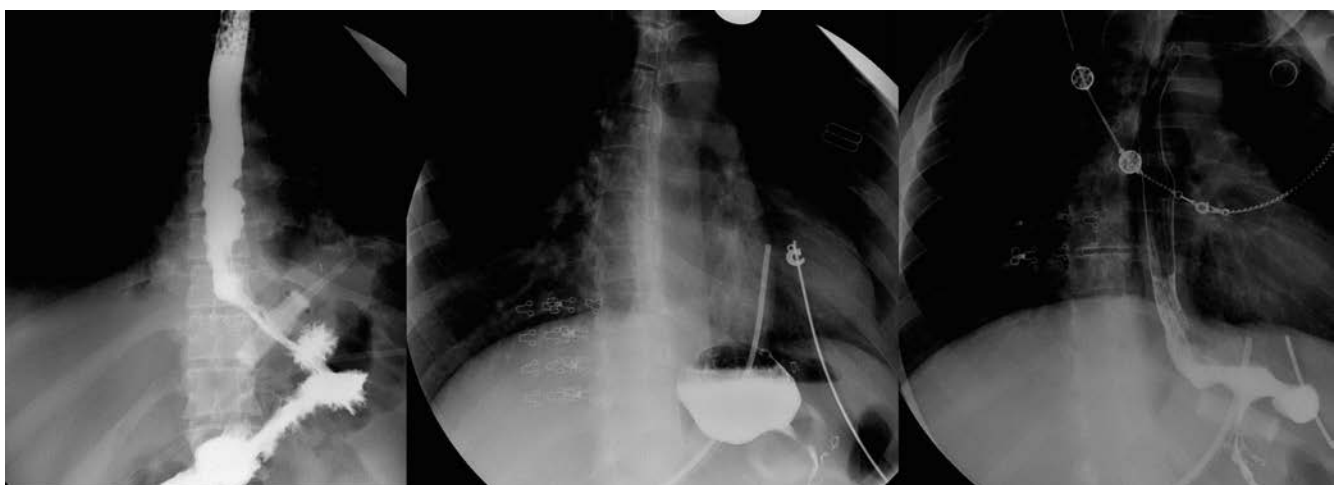


Figure 63.6 Band fluoroscopy in good position (left), pouch dilatation (middle), and anterior slippage (right).

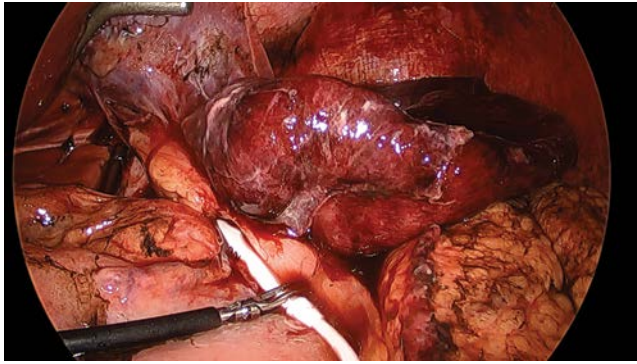


Figure 63.7 Band slippage with strangulation and ischemia.

simply excise the necrotic portion of the stomach. However, in order to maintain weight loss, and if the remainder of the gastric tissue appears viable, one can concurrently remove the band and diseased tissue while creating a sleeve gastrectomy or a Roux-en-Y gastric bypass.

Pouch dilation

Sometimes a patient can develop excessive stomach cephalad to the gastric band. On esophagogram the band is often in proper position, yet there is a concentric dilation of the gastric pouch, and often an associated dilation of the esophagus (Figure 63.6, middle). The etiology of concentric dilation is a result of adjusting the band too tightly, chronic patient noncompliance in the form of overeating, or a combination of the two. Clinically, once again, the symptoms include dysphagia, decreased satiety, acid reflux, nausea, and vomiting. Therefore, clinically it is difficult to assess whether the symptoms are a result of concentric dilation or prolapse. An esophagogram will make the diagnosis. Treatment simply involves decompression of the gastric band. After the symptoms resolve, often in a few weeks, the band can once again be slowly and systemically filled in a gentle manner.

Port and tubing problems

In the first few weeks after surgery, one can develop an infection of the gastric band port. This is often a result of a wound infection, and the port becomes collateral damage to the postoperative skin infection. In such cases, it is important to remove the port surgically, treat the infection with an incision and drainage, replace the tubing back into the abdominal cavity, and allow a few weeks of antibiotic treatment. Once the infection has resolved, one can return to the operating room to replace the port. If the port infection occurs later, as previously described, one must rule out band erosion. Once erosion is ruled out, one would treat the infected port as previously described.

Sometimes, as a patient loses weight and the contour of the abdominal wall changes, or as a result of failure of proper placement of the port against the anterior rectus sheath, the port can flip. In such cases, it becomes nearly impossible to access the port with a Huber needle. Radiographs help confirm that the port's position has shifted. In such cases, one should return to the operating room and reposition the port, assuring that it is properly sutured to the anterior rectus sheath. Furthermore, failed attempts at a band adjustment can sometimes result in the needle puncturing the extra-abdominal tubing leading to the port. In such cases, the patient fails to lose weight and denies the appropriate feeling of early satiety. One can assess how much fluid is present and finds that there is a leakage of saline. In such cases, the patient must return to the operating room to have a new access port placed. In the operating room, the surgeon can instill methylene blue through the access port to see from where the leak is occurring.

The tubing of the band is quite durable. However, it can, in rare circumstances, fail. Cases have been reported where the tubing develops a small hole or breaks in half. Once again, the patient feels a lack of proper "restriction," and the surgeon finds there is an inconsistently low amount of saline in the band (or none at all). In such cases, the patient is taken to the operating room. First, the port and extra-abdominal tubing are assessed with methylene blue to rule out extra-abdominal tubing leakage. If this is not found, it is important to laparoscopically assess the band and tubing. Once again, after instillation of methylene blue, one can see if there is a leak in the tubing of the band or the balloon of the band itself. Proximal tubing problems and balloon leakage require replacement of the device.

In rare cases, the gastric band tubing can cause a bowel obstruction. In such cases, the patient presents with usual signs of bowel obstruction. Nevertheless, the computed tomography scan often shows that the tubing has wrapped around a loop of small intestine. Any such finding should result in immediate laparoscopy to alleviate the obstruction.

OUTCOMES AND CONCLUSION

Since its early inception, augmented by perfected techniques of placement and systemic adjustments, the laparoscopic adjustable gastric band has become a safe alternative to stapled bariatric procedures. In general, one can expect 0.5–1 kg of weight loss per week with the band. This is generally achieved over a 2–3 year period of time. With proper follow-up, appropriate adjustments, and the attainment of early satiety, results may be varied but show approximately 40%–55% excess weight loss (%EWL). Many studies have been performed showing long-term outcomes of the gastric band, and some are more than 10-year studies. There is great variety in the results of these studies ranging from 25% to 70% EWL.¹¹ Also, an U.S. Food and Drug Administration gastric band trial demonstrated excess weight loss of 26.5%

at 6 months, 34.5% at 12 months, 37.8% at 25 months, and 36.2% at 36 months.¹² There have been meta-analyses performed that also give a good overview of results related to the gastric band. For example, Buchwald et al. reviewed just under 4,000 patients showing a mean %EWL of 47.5%.¹³ O'Brien et al. assessed nearly 4,500 gastric band patients and found %EWL to be 42.6% at 1 year, 57.5% at 3 years, 54% at 5 years, and 59.3% at 8 years.¹⁴

Outcomes of the gastric band are quite variable and practice specific. The bariatric practice must maintain an infrastructure that would allow an ease of patient flow for multiple adjustment visits. Also, availability of practitioners is key for managing gastric band patients. In bariatric surgery, we often say a LAGB patient's results are only as good as his or her surgeon's availability for follow-up. With proper follow-up, appropriate adjustments, and helpful support, the gastric band patient can see %EWL near 50%. This is comparable with many other bariatric procedures. The difference is, in exchange for the risks of a stapled procedure, the patient pays back in terms of a lifetime of follow-up, stricter food restrictions, and multiple adjustments until he or she senses appropriate satiety. The evolution of the LAGB technique and the management of this device

have provided us with a very safe alternative to the commonly performed stapled restrictive bariatric procedures. Nevertheless, a surgeon should decide if he or she is willing to provide the required follow-up before starting to perform this procedure.

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Laparoscopic Roux-en-Y gastric bypass

DAVID SPECTOR AND SCOTT SHIKORA

INTRODUCTION

In 1967 Dr. Edward Mason first described the gastric bypass as an operation for weight loss based on his observations of patients undergoing partial gastrectomies. It was essentially a loop gastric bypass with the stomach divided horizontally.¹ In the following years, the operation was slowly modified to become the gastric bypass that is known today. Since its inception almost 50 years ago, the gastric bypass has been the most popular bariatric operation worldwide. It has been challenged as the bariatric procedure of choice by many different operations that have come and gone. For example, the laparoscopic adjustable gastric band, which was at one time thought to become the bariatric operation of choice, has almost completely fallen out of favor. Today, for the majority of patients, there are two options: the sleeve gastrectomy (SG) or the Roux-en-Y gastric bypass (RYGB). Currently, in most academic practices, more and more bariatric patients choose the SG. However, the RYGB, almost exclusively performed laparoscopically (LRYGB), is still a very important procedure for any bariatric surgeon to be able to offer. Over the years, it has demonstrated itself to consistently produce meaningful and sustainable weight loss and improvements in the associated metabolic conditions in the majority of patients ([Figure 64.1](#)).

INDICATIONS FOR SURGERY AND THE PREOPERATIVE PREPARATION

In 1991, the U.S. National Institutes of Health assembled an expert panel to develop the criteria for offering patients bariatric surgery. Since then, little has changed. Patients must have a body mass index (BMI) ≥ 35 kg/m² and at least one obesity-associated health issue, such as obstructive sleep apnea, hypertension, or type II diabetes. Patients whose BMI is ≥ 40 kg/m² can be considered for bariatric

surgery even if they do not suffer from any of the comorbid conditions.

Just possessing a BMI ≥ 35 kg/m² does not automatically clear a patient for bariatric surgery. Patients must undergo a thorough screening process. This includes a medical evaluation to assess overall health, a behavioral analysis to assess for appropriateness for having surgery, and a surgical evaluation to assess for surgical risk. In addition, this multidisciplinary evaluation process functions as a valuable source of information for the patient. The procedures are reviewed, and the patient is given the information to determine which procedure he or she would prefer and whether that choice seemed appropriate. There are a number of considerations that generally make the RYGB the better surgical choice. These include robust gastroesophageal reflux disease, longstanding type II diabetes, and the presence of Barrett esophagus.^{2,3}

General concepts for performing a laparoscopic Roux-en-Y gastric bypass

ANTE-COLIC VERSUS RETRO-COLIC

One of the main concerns with the LRYGB is the tension on the gastrojejunostomy. Bringing the Roux limb through a small avascular window in the transverse mesocolon below the transverse colon (retro-colic) is a shorter distance for the Roux limb to travel to reach the gastric pouch and therefore puts less tension on the gastrojejunostomy. The downside of doing this is that creating the mesocolonic window can at times be difficult and necessitates dissecting in a space that contains large blood vessels. Furthermore, creating an opening in the transverse mesocolon also creates another place where an internal hernia could form. Last, the retro-colic positioning of the Roux limb makes it less accessible in the event that the patient subsequently requires additional surgery in the future ([Figure 64.2](#)).

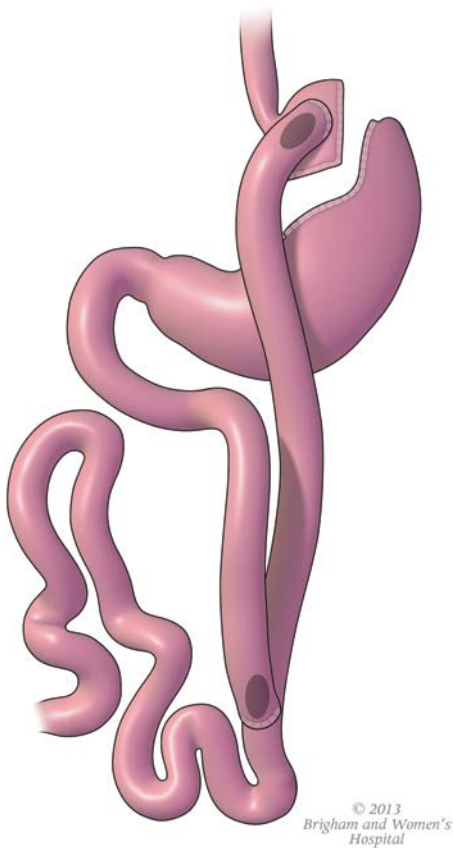


Figure 64.1 Roux-en-Y gastric bypass.

The Roux limb can also be brought up anterior to the transverse colon (ante-colic). This technique can be challenging as the Roux limb must travel a greater distance, which can result in greater tension than the retro-colic approach. This may occur when the mesentery of the Roux limb is short or when there is a large omentum and/or a

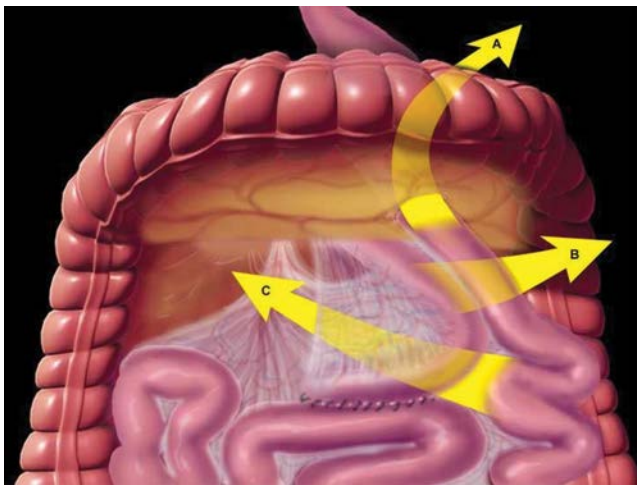


Figure 64.2 Possible locations of an internal hernia after a Roux-en-Y gastric bypass.

significant amount of intra-abdominal fat. This tension may increase the likelihood for anastomotic complications, such as leak, marginal ulcers, and anastomotic strictures. Techniques to reduce tension include anastomosing the Roux limb more distally than the stump end and splitting the omentum all the way to the gastroepiploic vessels.

The ante-colic approach is the most commonly used approach by bariatric surgeons. However, it is important to also be able to perform the LRYGB with a retro-colic approach when despite all maneuvers, the Roux limb cannot comfortably reach the gastric pouch. In this setting, reverting to a retro-colic approach may be indicated. After transecting the small bowel to create the Roux and biliopancreatic limbs, the stump end of the Roux limb is sewn to a Penrose drain. The transverse colon is retracted cranially, and the mesentery is opened in an avascular area just above the pancreas. The Penrose is inserted into this space and then found after the stomach pouch is created. Gentle pulling on the Penrose drain will deliver the Roux limb into the lesser sac, bringing it under the gastric pouch ready for the creation of the anastomosis. Rarely is unacceptable tension seen with this technique.

CLOSING THE SPACES OF POTENTIAL INTERNAL HERNIAS

As a consequence of the gastrointestinal tract rearrangement after an LRYGB, two or three spaces (determined by whether an ante-colic or retro-colic delivery of the Roux limb was employed) are formed that can potentially result in an internal hernia. Petersen space is formed underneath the cut mesentery of the Roux limb. It is framed by the small bowel and its mesentery anteriorly, the retroperitoneum posteriorly, and the transverse colon and mesocolon, superiorly. This space is smaller and more concerning with the retro-colic approach. The intermesenteric space is formed under the jejuno-jejunostomy. The third space is unique to the retro-colic LRYGB and can form alongside the Roux limb as it sits in the mesocolonic tunnel. Through any of these three spaces, the Roux limb, the biliopancreatic limb, or even the common distal channel can herniate, incarcerate, and potentially become obstructed—even strangulate.⁴ Most bariatric surgeons would agree that it is therefore important to thoroughly close these spaces with nonabsorbable sutures.

LENGTH OF THE ROUX LIMB

There is no consensus as to the proper length of the Roux limb. Roux limbs shorter than 50 cm are considered unwise, as they might result in bile reflux into the gastric pouch and esophagus. Most bariatric surgeons create Roux limbs between 100 and 150 cm in length. For patients with a BMI > 50 kg/m², there is some evidence demonstrating a correlation between Roux length and weight loss. This has not been shown to be the case for patients with a BMI < 50 kg/m².⁵ Also, increased length of the Roux limb length corresponds to a more robust antidiabetic effect. Although fat malabsorption has been found to be variable, it is commonly thought to be very low with a Roux limb of up

to 150 cm, and consequently unlikely to cause bowel habit changes like diarrhea.⁶ Our practice is to create Roux limb lengths of 100–150 cm for patients with a BMI < 50 kg/m² and for patients with BMI > 50 kg/m², to create Roux limbs of 150–200 cm.

Operative technique

PREOPERATIVE PREPARATION

Before the patient is taken into the operating room, the patient receives a subcutaneous injection of 5,000 units heparin and an intravenous (IV) dose of a third-generation cephalosporin. The patient is placed in a supine position, and general anesthesia is induced. It is important to completely flatten the patient and remove all towels elevating the back. Sequential compression devices are placed on the calves. An orogastric tube is placed in the stomach. A urinary catheter may be employed as per the surgeon's usual practice. The patient is positioned with the arms extended. A footboard is attached to the bed to stabilize the patient during the surgery. The surgeon and the camera operator are on the patient's right, with the surgical assistant on the left. Some surgeons prefer to operate between the legs using a split leg table.

ABDOMINAL ENTRY AND TROCAR PLACEMENT

A Veress needle is inserted into the left upper quadrant, and pneumoperitoneum is achieved to a pressure of 18 mm Hg. The trocars are inserted under laparoscopic visualization. The trocar placement includes a camera port (5 mm or 11 mm; depends on the optics used) just above and to the left of the umbilicus. Two 5 mm ports are placed in the left upper abdomen. A 5 mm port is placed in the right upper abdomen, and a 12 mm port is placed approximately 10 cm below it and 10 cm to the right of the camera port. A nick in the subxiphoid position is made, and a Nathanson liver retractor is inserted and the liver lifted away from the stomach.

JEJUNO-JEJUNOSTOMY

The patient is put in a moderate reverse Trendelenburg position. The omentum and transverse colon are retracted cranially. At the base of the transverse mesocolon, the most proximal jejunum is found at the ligament of Treitz. The bowel is run 40 cm and transected with a 60 mm linear stapler with varied staple heights from 3 to 4 mm. The proximal limb is designated the biliopancreatic limb (BPL) and the distal limb, the Roux limb. It is of critical importance to avoid confusing which limb is the Roux and which is the BPL. One useful technique is to mark the Roux limb with suture or hemoclips. The mesentery is divided with a bipolar vessel sealing device to its base. It is important to take enough of the mesentery so that the stump of the Roux limb can easily reach the area of the gastric pouch. The transected edge of the Roux limb is run 100–200 cm distally (depending on the patient's BMI) while orienting the Roux limb in a counterclockwise fashion toward the right abdomen. The

transected edge of the BPL is placed alongside the measured area on the Roux limb. A side-to-side anastomosis is performed. Two antimesenteric enterotomies are made on the two limbs. A 60 mm linear stapler with varied staple heights from 3 to 4 mm is inserted and fired in a side-to-side fashion. The resulting enterotomy is closed with a transverse running silk suture. The mesentery is then also closed with a running silk suture. The first two bites align the transected edge of the BPL to the common channel as the antiobstruction (Brolin) stitch. Care should be taken when closing the base of the mesenteric defect to avoid shortening the freed mesentery of the Roux limb, creating a mesenteric hemorrhage or injuring the blood supply to the Roux limb. The omentum is then split with a bipolar vessel sealing device to about 2 cm from the gastroepiploic arcade.

GASTROJEJUNOSTOMY

The patient is now placed in a deep reverse Trendelenburg position. It is essential to communicate with the anesthesia team to ensure that all tubes are removed from the stomach, leaving only an endotracheal tube in the mouth. The lesser sac is entered by opening the pars flaccida near the incisura of the lesser curvature. The vascular arcade in the mesentery of the stomach to the right of the lesser curvature and just below the left gastric vessels is transected with a 60 mm linear stapler with varied staple heights from 3 to 4 mm. The pouch is formed with sequential firings of the stapler with cartridges of the same cartridge size. This is started along the lesser curvature, just distal to the left gastric vessels near the second gastric arcade. The first stapler is fired transversely across the stomach. This is continued from the edge of the previous transection toward the angle of His. It is important to completely divide the formed pouch from the gastric remnant by ensuring that the last staple line is past the edge of the stomach to prevent a possible iatrogenic gastrogastric fistula.

The posterior aspect of the formed pouch is cleared of fat. A small gastrostomy is made on the posterior aspect of the pouch 2 cm from the transverse staple line, and an enterotomy is made on the antimesenteric side approximately 4 cm from the cut end of the Roux limb. One arm of a 30 mm linear stapler with varied staple heights from 3 to 4 mm is inserted into the enterotomy, and the stapler is temporarily closed. The Roux limb is then transported up to the pouch by the stapler, and the second arm of the stapler is then inserted into the gastrostomy and fired. The anesthesia team is asked to insert an orogastric tube (OGT). This is passed through the pouch into the proximal Roux limb. The anastomosis is then completed by suturing the remaining defect closed with two layers of absorbable continuous sutures. The second suture line is made to the stapled pouch end to remove tension from the first internal suture and cover the anterior side of the anastomosis with the Roux limb serosa.

The gastrojejunostomy and pouch are tested to ensure that there is no leakage. The patient is positioned flat. The Roux limb is cross-clamped just distal to the tip of the OGT.

The left upper quadrant is flooded with water. The OGT is connected to oxygen and insufflated at 2 L/min. The anastomosis is observed distending, and care is made not to overdistend it. If distention is not observed, some careful pressure on the cricoid cartilage can help. The OGT is put back on suction and then removed.

The lower edge of the Petersen space is closed with a running nonabsorbable suture between the mesentery of the Roux limb and the transverse mesocolon. When placing this suture, it is crucial to avoid injuring the blood supply to the Roux limb. Some surgeons place a drain positioned along the gastrojejunostomy. The incisions are injected with long-acting local anesthesia and closed with intracutaneous absorbable sutures and covered with biologic glue. The 12 mm port site is also sutured closed at the fascial level to reduce the risks of port site herniation.

The above operative procedure description only represents one of many different techniques that are currently being performed. All of the techniques have benefits, and to date, there is no solid evidence to support one over another. For example, the gastrojejunostomy could have been created without a stapler, entirely hand sewn. Additionally, it could have been created using a circular stapler whose anvil is passed transabdominally or even transorally.

Postoperative care

EARLY POSTOPERATIVE CARE

Thromboembolic prophylaxis is important in this population. Sequential compression devices placed on the calves are used whenever the patient is in bed. Aggressive early ambulation is employed. Essentially all patients are given subcutaneous heparin injections every 8 hours. Patients with a BMI > 55 and those with a high risk for thromboembolism are started postoperatively on low molecular weight heparin and continued for 28 days after surgery. Pain is controlled with patient-controlled analgesia. If there is no evidence for bleeding or renal disease, an IV nonsteroidal anti-inflammatory medication is added. Patients may be allowed small sips of water the night after their surgery. The day after surgery the patient is allowed to start sugar-free liquids and, if tolerated, protein shakes that evening. The patient can be discharged when able to tolerate this diet, maintain hydration, and control pain with oral medications. If a drain was placed, it is usually taken out just before discharge.

EARLY POSTOPERATIVE COMPLICATIONS

In this patient population, the abdominal exam can be misleading. A leak from the anastomosis can be hard to diagnose. A normal abdominal exam should not rule this out. It is suggested that the thick abdominal wall in morbidly obese patients can diminish findings on physical exam. It is very possible that the only abnormal parameter in this scenario is tachycardia. Patients with a sustained pulse above 120 bpm should be considered to have a leak and

proper action taken. In hemodynamically stable patients, the workup should include blood work to exclude bleeding and imaging, either an abdominal computed tomography (CT) scan with oral contrast or an upper gastrointestinal series. If the patient is unstable or concerning for instability, he or she should be taken immediately back to surgery foregoing imaging studies. Broad-spectrum antibiotics and resuscitative IV fluid should be initiated early ([Table 64.1](#)).

The most common site of a leak is the gastrojejunostomy. Management of a suspected leak in the first 2–3 days will generally include taking the patient back for surgery. A robust washout of the abdomen with good placement of drains is the best treatment. It is sometimes possible to find the leak and close it with an omental patch. However, immediate repair of the leak is often not possible or successful because of the inflammatory reaction of the tissues. Getting control of the source of sepsis is the first priority. Consideration should also be given to establishing enteral feeding access with a gastrostomy to the gastric remnant or feeding jejunostomy. The peritoneal fluid should be sent for culture; broad-spectrum antibiotics are continued until they can be tailored based on the cultures.

Patients found to have a small contained leak can sometimes be managed conservatively with antibiotics, nothing by mouth, and enteral or parenteral nutrition. Additionally, there is an increasing experience for endoscopic treatments such as stents or endoscopic suturing.

Postoperative bleeding can be intraluminal or intra-abdominal. Intraluminal bleeding is usually from one of the anastomoses, with the gastrojejunostomy being the most common culprit. In this scenario, there is minimal abdominal tenderness on exam. There may or there may not be hematemesis or hematochezia. When clinical findings suggest robust bleeding from the gastrojejunostomy, surgical oversewing of the gastrojejunostomy is often successful. Bleeding in the peritoneal cavity usually presents with a distended tender abdomen. Surgical exploration will typically not find the bleeding source or active bleeding, but removal of the intra-abdominal blood and clot is advantageous.

Table 64.1 Early complications after laparoscopic Roux-en-Y gastric bypass

Wound infection	0.2%
Urinary tract infection	0.91%
Pneumonia	0.5%
Bleeding requiring transfusion	1.5%
Abscess/sepsis	0.6%
Deep vein thrombosis	0.21%
Pulmonary embolism	0.21%
Stroke	0.03%
Myocardial infarction	0.1%
Serious morbidity	5.8%
Mortality	0.2%

Source: Young MT et al. *J Am Coll Surg* 2015;220(5):880–5;¹³ Rausa E et al. *Obes Surg* 2016;26(8):1956–63.¹⁴

Patients who are hemodynamically stable may be managed conservatively. Often the bleeding will spontaneously cease. Transfusions may be required. In many bariatric practices, bleeding at the gastrojejunostomy is managed endoscopically. If a bleeding site is observed, it can be controlled with clips, suture, or the injection of epinephrine.

Pulmonary embolism should always be included in the differential diagnosis of postoperative patients with tachycardia, tachypnea, or chest pain. There should be a low threshold for ruling this out with a chest CT. The workup of unexplained tachycardia will often include a concomitant chest CT with IV contrast and an abdominal CT with oral contrast.

LONG-TERM POSTOPERATIVE MANAGEMENT

After LRYGB, patients are placed on a multivitamin and calcium regimen for life. Long-term follow-up has been shown to improve weight loss, but equally as significant, it allows for continual patient monitoring. In our program, patients are typically seen in clinic in the first year every 3 months, in the second year every 6 months, and annually after that. Standard laboratory tests with a wide vitamin panel are done at these times.

LATE COMPLICATIONS

A marginal ulcer can form at the gastrojejunostomy on the Roux limb side. This commonly manifests as epigastric pain. It also can cause dysphagia and vomiting. The diagnosis is confirmed with endoscopy. It is important to rule out an anatomical etiology that includes a gastrogastic fistula or an acid-producing gastric pouch that is too large. These can usually be demonstrated on an upper gastrointestinal series. If one of these is found, revisional surgery may be needed to reduce the pouch size or resect the fistula. If an anatomical reason is not found, the etiology is almost always lifestyle related, such as tobacco smoking, chronic nonsteroidal anti-inflammatory medication use, or alcohol abuse. In this setting, stopping the inciting factor together with sucralfate and proton pump inhibitors will usually be effective. The ulcers are not likely to resolve if a gastrogastic fistula is present or the patient continues to smoke, drink alcohol, or take nonsteroidal anti-inflammatory medications.

Internal hernias remain a diagnostic challenge for patients after LRYGB. The accepted management for postoperative small bowel obstruction (SBO) after open surgery is based on the most common etiology being adhesions. It has been demonstrated that after LRYGB the main reason for SBO is internal hernias.⁷ Obstruction caused by an internal hernia is usually treated surgically rather than nonoperatively because of the elevated risk of closed loop obstruction. The BPL composed of the proximal jejunum, duodenum, and drains of the excluded fundus is a diverted segment of the gastrointestinal tract, and when obstructed, may form a dangerous closed loop that can result in necrosis and perforation of the limb or the gastric remnant. In this setting, radiological and clinical evidence of obstruction is commonly not found. Abdominal CT has been shown to have false-negative rates

of 20%–35% for internal hernias in patients after LRYGB. The patient may only have nausea and worsening abdominal pain in the right upper abdomen. Moderately elevated levels of amylase or lipase (low hundreds) have been shown to be very sensitive (94%) for obstruction of the BPL. We recommend obtaining an abdominal CT as well as serum amylase or lipase levels for all patients with abdominal pain who have had an LRYGB. There should also be a very low threshold to laparoscopically explore patients after LRYGB with clinical acute or chronic SBO.⁴

Dumping syndrome is a combination of postprandial symptoms that occur in patients after gastric bypass. The syndrome is noteworthy to have an early and a late phase. The symptoms in the early phase occur within the first hour after eating food with refined sugar, such as soda, sweets, or ice cream. The symptoms include abdominal pain, borborygmi, nausea, fatigue, facial flushing, and palpitations. The late phase occurs within 1–3 hours after eating, and is symptomatic hypoglycemia induced by hyperinsulinemia. Early phase dumping is experienced by approximately 10%, and late phase dumping by 7% of patients after gastric bypass. Patients at higher risk of this are females, BMI < 25 and younger age.⁸ The first line of treatment is dietary counseling to avoid sweets and to consume meals high in protein. If dietary manipulation is unsuccessful, medications such as Acarbose may be considered. Patients with intractable symptoms can be referred to an endocrinologist to work them up for other causes or symptoms such as an insulinoma. Rarely, a pancreatic resection or gastric bypass reversal might be considered for patients with dumping syndrome.

LONG-TERM OUTCOMES

Diabetes remission after gastric bypass has been shown to be approximately 80%.^{9,10} The longer the patient has had the diagnosis and the more medications that are needed to achieve glycemic control (more robust and longstanding disease), the lower is the remission rate. The improvement in glycemic control is often within days after surgery, demonstrating a weight-independent antidiabetic effect.¹¹ After gastric bypass, restarting diabetic medications should be done with caution to avoid hypoglycemia. Remission rates for hypertension are 75%. This happens more gradually over a few months. Antihypertensive medications can be restarted after surgery and gradually reduced. Dyslipidemia remission is 68%–76%. Remission from obstructive sleep apnea is higher at 90%–96%. Weight loss 3 years after gastric bypass is on average, 57%–67% excess weight loss.¹²

CONCLUSIONS

RYGB is still the gold standard operation for the surgical treatment of obesity. While the development of new alternative procedures and different surgical options continues, gastric bypass will probably remain an important operation for many years.

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Laparoscopic sleeve gastrectomy

JIHUI LI, EMANUELE LO MENZO, SAMUEL SZOMSTEIN, AND RAUL J. ROSENTHAL

INTRODUCTION

The bariatric procedure commonly referred to as sleeve gastrectomy (SG) is a partial gastrectomy of the gastric fundus and body that creates a long, tubular gastric conduit along the lesser curve of the stomach (**Figure 65.1**). It was first described as a part of a duodenal switch bariatric surgery in 1990.¹ Laparoscopic sleeve gastrectomy (LSG) was subsequently performed by Gagner and was proposed as a first stage of a bariatric protocol for high-risk patients to reduce the risk profile of laparoscopic duodenal switch.² However, LSG rapidly became a stand-alone bariatric procedure worldwide because of its simplicity and efficacy.³ Several International Consensus Summit for Sleeve Gastrectomy meetings have been held to discuss the technique and its effectiveness.^{4–7} The Third International Summit for Sleeve Gastrectomy presented 19,605 LSG procedures from 88 surgeons, during which they found that a second-stage procedure became necessary only in 2.2% of patients. The mean percentage of excess weight loss (% EWL) in this group at 1, 2, 3, 4, and 5 years was 62.7%, 64.7%, 64.0%, 57.3%, and 60.0%, respectively. The summit concluded that the weight loss and improvement in diabetes appear to be better than with laparoscopic adjustable gastric banding (LAGB) and on par with Roux-en-Y gastric bypass (RYGB).⁶ The American College of Surgeons Bariatric Surgery Center Network has put LSG in the intermediate position between LAGB and RYGB in terms of surgical risk, weight loss, and resolution of obesity-related illness.⁸

SG is generally referred to as a restrictive procedure, but the mechanisms of weight loss as well as improvement in comorbidities observed after surgery could also be related to neuroendocrine changes after gastric resection and expedited nutrient transport into the small bowel. One of the changes is the decrease of production of ghrelin by removing most of the stomach. Ghrelin functions as a neuropeptide in the central nervous system and reduces hunger, and

it also plays a significant role in regulating the distribution and rate of use of energy. With rapid accumulation of the numbers of SG performed, research on its metabolic mechanisms continues to be a hot spot.⁹

PATIENT SELECTION

The National Institutes of Health (NIH) criteria of bariatric surgery for morbid obesity, which many countries follow, are usually defined as BMI (Body mass index: Weight in kilograms/square of height in meters; kg/m²) over 40, or BMI 35–40 with comorbidities. These were generated by a consensus conference convened by the NIH in the United States in 1994, at a time when most cases were performed via open approach using gastric stapling techniques, with relatively high surgical morbidity and mortality rates. However, there is now level 1 evidence of greater weight loss and better health and quality of life after bariatric surgery compared with lifestyle therapy in morbidly obese patients, as well as in the mild to moderately obese patients (BMI 30–35).¹⁰ For patients with diabetes, bariatric surgery demonstrates a dominant level of cost-effectiveness, with an increased number of quality-adjusted life-years at a lower cost than nonsurgical therapies. As a result, there is increasing support for a BMI of 30 as the lower cut-off.¹⁰

In the International Sleeve Gastrectomy Expert Panel Consensus Statement, LSG was identified as a valid treatment option for the following categories of patients with morbid obesity: Patients with high risk (96%); transplant candidates (kidney and liver) (96%); patients with metabolic syndrome (91%); BMI of 30–35 with associated comorbidities (95%); patients with inflammatory bowel disease (86%); adolescent patients (77%); elderly (100%); and patients with Child's A or B liver cirrhosis (78%). LSG is only appropriate as a first-stage procedure for the super morbidly obese patient in a two-step approach (75%).⁷

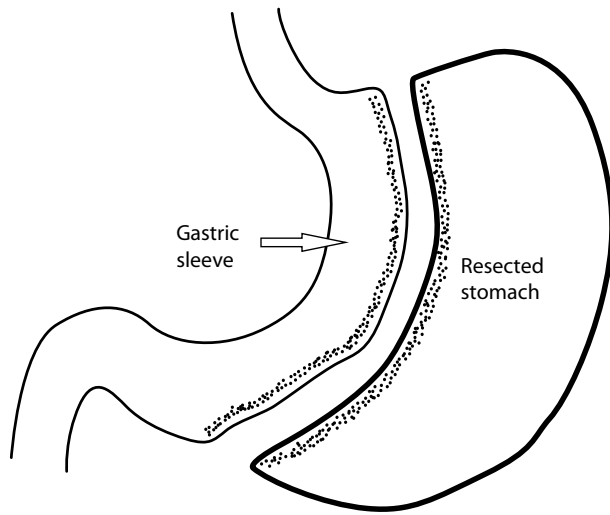


Figure 65.1 Sleeve gastrectomy.

SURGICAL TECHNIQUE

Access to the abdominal cavity to perform LSG has varied with surgeons based on their training and experience. Principles of port placement include optimal view of surgical field from the camera port; switching the camera to other ports to get an optimal view with progression of the surgical procedure; direct access to the target structure from operative ports; and switching the port and adjusting angles of the articulating stapler to achieve direct alignment of the stapler with the planned staple line.

The esophageal hiatus should be assessed, and hiatal hernia should be properly dissected and repaired if identified. Omentum attached to the great curvature is dissected from the stomach using energy sources. A 36–40 Fr bougie, the preferred size, is passed and placed along the lesser curvature of the stomach. The greater curvature of the stomach is transected starting from 5 to 8 cm proximal to the pylorus, along the guidance of the bougie to the fundus of the stomach using the stapler. Proper cartridges with different heights of staples are used to transect different parts of the stomach according to the thickness of the stomach wall, which decreases from the pylorus to the fundus. Attention is paid to avoid narrowing at the incisura angularis. Gentle traction at the stomach is applied while positioning the stapler to avoid twisting the sleeve. About 1 cm of gastric tissue to the left of the angle of His is left to avoid ischemia. A leak test can also be performed by injecting air or methylene blue via bougie or endoscope when its tip is withdrawn back to the level of esophageal hiatus. To further secure the staple line, some choose to use buttress material or fibrin glue, oversew the staple line, or reattach the staple line to the omentum. The resected stomach is removed from an enlarged port site. Some also place a closed suction drain, which is then removed in early postoperative days.

RESULT

According to the medium-term follow-up after LSG, the mean %EWL varies from 33% to 90% at up to 3 years.^{11–13} Substantial weight reduction with mean %EWL ranging from 48% to 86% was also observed at more than 5 years after LSG. In the longest follow-up data available, 85% of patients had more than 20% actual weight loss over 8 years after LSG,¹⁴ which was comparable with those at 10 years after RYGB (73.5% had more than 20% actual weight loss) in the Swedish Obese Subjects Study.¹⁵

A meta-analysis of four randomized controlled trials also found no significant difference between RYGB and LSG groups with regard to levels of glycosylated hemoglobin, fasting plasma glucose, the numbers of subjects using oral anti-hyperglycemic medications and insulin, body weight, BMI, or waist circumference. However, cardiovascular risk was significantly less in the RYGB group. It concluded that compared with LSG, RYGB offered an equal efficacy for the treatment of diabetes in obese patients but was additionally associated with a significantly decreased cardiovascular risk.¹⁶

Multiple studies have shown improvement of type 2 diabetes mellitus and hypertension after LSG during follow-up.^{17–21} The improvements in serum glucose and blood pressure control occur within 6 months after surgery and are often significant enough to result in discontinuation or decreased dosages of related medications.²²

COMPLICATIONS AND MANAGEMENT

Leak, stricture, and bleeding are the most prevalent complications observed after LSG.

Leaks: Recent series have reported a rate of 1%–2% of leaks, and leaks are considered to be the most serious complication of this procedure.²³ Most leaks occur in the proximal third of the stomach, close to the gastroesophageal junction. SG creates a long staple line with increased intraluminal pressure. Causes of leak and fistula formation are related to these, and include staple failure, ischemia, and distal stenosis.²⁴ Leaks can be classified based on time of presentation after surgery as acute (within 7 days), early (within 1–6 weeks), late (after 6 weeks), and chronic (after 12 weeks). Patients with leak can present with fever and tachycardia but with normal findings from upper gastrointestinal radiograph or other studies. An unstable patient with a contained or uncontained leak requires immediate intervention. If conservative therapy has failed, a stent is a valid treatment option for an acute proximal leak. It is recommended to wait until after 12 weeks of conservative therapy before surgical repair of a proximal leak (converting to bypass or revising sleeve).⁷

Stenosis: Stenosis is another possible complication after LSG. It may appear acutely after surgery but usually presents chronically, with incidence rates between 0.1% and 3.9%.²⁴ In most cases, it is a short segmental stenosis located in the body, near the incisura angularis, and less

frequently at the proximal level. Possible causes of stenosis are edema and postoperative hematomas, but it may also be related to suture reinforcement, usage of an excessively small bougie size, or staple line angulations that create torsion.²⁴ Stenosis can be treated by observation, endoscopic dilation, seromyotomy, and even conversion to RYGB based on time and severity of presentation.

Bleeding: Sources of bleeding after LSG can be the gastric staple line, the omentum, the short gastric vessels, and the port sites in the abdominal wall. Most bleeding complications come from the long staple line on the stomach, which is rich in blood supply. Different methods to decrease bleeding have been studied, including the use of buttress materials, application of fibrin glue, and placement of stitches, all with various results. All port sites should be inspected for bleeding, especially the site of specimen extraction before closure.²⁵

CONCLUSION

LSG was the first element of the duodenal switch procedure, and it has now become the most popular stand-alone bariatric procedure. However, its perceived technical ease should not be underestimated, and long-term close follow-up is necessary to achieve excellent long-term results. LSG has proven to result in resolution of comorbidities, and achieves good to excellent quality of life scores and good food tolerance. Evidence supporting bariatric (metabolic) surgery including LSG is strong. As an independent bariatric procedure, LSG has been proven as safe and effective, and its durability should be fully evaluated.

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Laparoscopic management of bariatric surgery complications

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INTRODUCTION

As is inherent with any surgery, bariatric surgery carries some degree of risk, and the decision to operate is made after a careful balance of the risks versus the benefits.

To address the problem of morbidity and mortality, it is important to predict the patients who will develop complications after bariatric surgery. According to a recent study of more than 44,000 patients from the United States, the following factors were independent predictors of increased complications: Age older than 45 years, male gender, a body mass index (BMI) of 50 kg or higher, open bariatric procedure, diabetes, prior coronary intervention, dyspnea at preoperative evaluation, bleeding disorders, and more than 10% unintentional weight loss in 6 months.^{1,2}

Every effort must be made to prevent complications, and this requires a process that starts with the proper setup of the bariatric program. A multidisciplinary team should include registered dietitians, medical specialty staff, a radiology suite that can cater to morbidly obese patients, operating room staff who are specifically trained for minimally invasive bariatric surgery, and an adequately trained surgeon are all necessary components of a comprehensive program dedicated to bariatric surgery.

In addition to early diagnosis, the optimal management of complications following bariatric surgery requires prompt intervention.

BARIATRIC SURGERY COMPLICATIONS

There are many types of bariatric surgeries performed all over the world, but here we concentrate on the most commonly performed surgeries and on the management of their

relative complications: Laparoscopic Roux-en-Y gastric bypass (LRYGB), laparoscopic sleeve gastrectomy (LSG), and laparoscopic adjustable gastric banding (LAGB) (Table 66.1).

Postoperative complications of gastric bypass surgery can be divided into acute (7 days), early (7 days to 6 weeks), late (6–12 weeks), and chronic (>12 weeks).

There are many medical complications following bariatric surgery, such as deep venous thrombosis, pulmonary embolism, myocardial infarction, weight regain, and nutritional deficiencies. However, in this chapter we focus on the most common surgical complications and those usually managed laparoscopically.

BYPASS-RELATED COMPLICATIONS

Anastomotic leak

Gastrointestinal leakage is one of the most devastating complications that can be encountered following bariatric surgery. The incidence of leaks following LRYGB is 1%–5%, and it mainly presents with nonspecific signs of sepsis, such as tachycardia, tachypnea, hypoxia, fever, leukocytosis, and hypotension. The clinical manifestation of a leak is usually within the first 10 days postoperatively, and it is often subtle, as morbidly obese patients usually present with a soft abdomen even in cases of peritonitis. Strategies to prevent leaks are important and can be summarized as the following: (1) avoiding devascularization of the gastric pouch, (2) avoiding excess tension at the gastrojejunal anastomosis, (3) oversewing the staple lines in revisional surgery, and (4) identifying and repairing leaks intraoperatively by using leak test with air or with methylene blue dye. As far as the clinical presentation, it is well established how a sustained

Table 66.1 Bariatric surgery complications

Common bariatric procedures	Common complications + incidence
LRYGB	• Leak (1%–5%)^{3–7} • Bleeding (1.9%–4.4%)^{5,8,9–11} • Anastomosis stricture (3%–11%)^{16,17} • Internal hernia (1%–9%)^{12–15} • Marginal ulcer (1%–16%)^{18,19} • Gastrogastic fistula (1.5%–6%)^{20,21}
LSG	• Leak (primary procedure 1%–3%)²² (revision procedure >10%)^{23–25} • Bleeding (1%–6%)^{26,27} • Stricture (3.5%)²⁸
LAGB	• Acute band slippage (1%–3%)²⁹ • Band erosion (4%)³⁰

tachycardia with a heart rate in excess of 120 beats per minute is a good indicator of an anastomotic leak.⁵ The clinical diagnosis is certainly the most important, and radiographic confirmation remains secondary. In fact, the necessity of routine upper gastrointestinal (UGI) contrast studies has been questioned by some groups because of the potential for false-negative results.⁵ However, UGI within the first 24–36 hours postoperatively remains a standard practice among many bariatric surgeons.^{5–7} Upper gastrointestinal series and computed tomography (CT) are the two commonly performed diagnostic procedures performed to rule out gastrointestinal leakage. The sensitivity of these modalities varies depending on patient-related factors and the experience of the interpreting radiologist. Limitations of UGI series entail the inability to visualize all potential sources of gastrointestinal leaks; therefore, CT scanning is more sensitive in this regard. In fact, leaks from the gastric remnant or jejunojejunostomy are not usually identifiable with UGI. A recent retrospective analysis of postoperatively collected data on 3,018 patients demonstrated that leaks were detected in 17 of 56 patients (30%) when UGI series were used and in 28 of 50 patients (56%) when CT scans were used.³¹ Another advantage of abdominal and pelvic CT scanning is the ability to reveal other intra-abdominal pathologies that share similar clinical symptoms to gastrointestinal leakage, such as small bowel obstruction or intra-abdominal bleeding. A potential limitation of CT scan is the inability to perform the procedure due to weight limitations or the inability of patients to fit inside the scanner. It is paramount to remember that an unstable patient suspicious of gastrointestinal leakage should be explored immediately without the need for any additional testing or radiological studies.

Laparoscopic exploration may be challenging even for experienced laparoscopic surgeons because of bowel distension and acute inflammation leading to adhesions and obliteration of tissue planes. At the time of exploration, all staple lines in addition to gastrojejunostomy and jejunojejunostomy anastomosis and the gastric remnant should be carefully inspected to help localize the site of the leak. Gentle, blunt

dissection can minimize serosal injuries or enterotomies to the gastric pouch or the Roux limb secondary to the severe inflammatory reaction. When a leak is identified, suture repair may be attempted, but most often the tissue is very fragile, so, omental patch if possible can be used to cover the site of leakage. Abdominal washout and wide drainage are recommended and the mainstay of treatment. If the site of leakage is not identified, abdominal washout and wide drainage are advised. Whenever feasible, placement of a feeding gastrostomy into the gastric remnant should be performed, as this would allow for continued enteral nutrition while bowel rest is maintained at the site of the anastomosis leakage.

In stable patients with a controlled leak, nonoperative management may be considered. A drain can be placed via interventional radiology with antibiotic administration and parenteral nutrition. In the presence of clinical deterioration or failure of clinical improvement, the patient should be explored immediately.

POSTOPERATIVE BLEEDING

Postoperative bleeding is a serious early complication following LRYGB. There are two types of postoperative hemorrhage. In the first kind, the bleeding occurs into the abdominal cavity (intra-abdominal). This is usually originating from the staple line at the gastrojejunostomy, the gastric pouch, the jejunojejunostomy, the excluded stomach, or injury to intraabdominal organs, including liver and spleen. In the second type of bleeding, the source is intraluminal, and patients may present with hematemesis when the bleeding originates from the gastrojejunostomy anastomosis, or melena if bleeding is from the newly formed jejunojejunostomy or the gastric remnant staple line. Management of unstable patients includes placement of large-bore intravenous lines with fluid and blood resuscitation, and suspension of anticoagulation treatment, as a first line of treatment. Intraoperative endoscopy is a useful adjunct, both diagnostically and therapeutically. In fact, in addition to helping localize the bleeding, many endoscopic modalities (clip application, epinephrine injection, and electrocautery) can successfully control gastrointestinal bleeding and prevent the need for surgical intervention. Laparoscopic surgical exploration may be indicated when the source of bleeding cannot be identified. At the time of laparoscopic exploration, intraluminal and intra-abdominal clots should be evacuated and the staple lines oversewn.^{11,32–33} The management of gastrointestinal bleeding in stable patients may be resuscitation only; however, if there is ongoing bleeding or the patient becomes unstable, endoscopic treatment, surgical exploration, or a combination of both is needed.

SMALL BOWEL OBSTRUCTION

The rate of postoperative bowel obstruction following laparoscopic bariatric surgery ranges from 0.6% to 3.5%. The

mean time to presentation is variable, with some authors reporting early obstruction within 15 weeks after a retrocolic approach,³⁴ and others describing later obstruction with antecolic approach as long as 1–3 years.³⁵ Causes of post-LRYGB intestinal obstruction include internal hernia, formation of mesocolic constrictions, anastomotic strictures, intussusception, and volvulus or kinking of the bowel distal to the Roux limb at the site of jejunojejunostomy. Internal hernias can occur at any of three defects created during gastric bypass. These defects include the transverse mesocolic window, the jejunojejunostomy mesenteric defect, and the space between the transverse mesocolon and the mesentery of the Roux limb (Peterson defect), accounting for 67%, 21%, and 7.5%, respectively. Additionally, another 4.5% of the internal hernias occur at more than one site.³⁶ Because of the elimination of the mesocolic defect, the antecolic placement of the Roux limb is associated with a low risk of obstruction of 0.43% compared to the retrocolic loop of 4.5%.³⁵ Furthermore, rapid weight reduction following gastric bypass may result in decreased intraperitoneal fat that may enlarge the mesenteric defect, facilitating hernia formation.³⁷ Patients who present with signs and symptoms of intestinal obstruction should undergo laparoscopic exploration. Operative treatment includes hernia reduction and closure of all mesenteric defects. Early and aggressive management of intestinal obstruction following LRYGB is essential to prevent the dangers of closed loop obstruction and acute dilatation of the remnant stomach. The morbidity of postoperative bowel obstruction remains high, with an incidence of perforation of 9.1% and death 1.6%.³⁶

Several strategies have been applied to minimize the incidence of internal hernia by meticulous closure of all potential defects with a continuous running technique.³⁶ However, even closure of these defects does not eliminate this dangerous complication, and sometimes, a poorly closed defect can cause more strangulation in case of a hernia than a wide open defect with a large hernia. In order to prevent kinking at the jejunum distal to the jejunojejunostomy, some authors advocate the use of a single nonabsorbable suture between the jejunum immediately distal to the anastomosis and the stapled end of the biliary limb.³⁸

SLEEVE GASTRECTOMY-RELATED COMPLICATIONS

Hemorrhage

The risk of postoperative bleeding after LSG has been reported between 1% and 6%. The source of bleeding can be intraluminal or extraluminal, and it usually presents with a serial drop in hemoglobin levels or signs of tachycardia or hypotension. Common sources are gastric staple line, spleen or liver injury, and abdominal wall at the site of trocar entry. Management of gastrointestinal bleeding always starts with resuscitation first; this includes establishment of large-bore intravenous lines for fluid, administration of

packed red blood cells if necessary, and accurate measurement of urine output with insertion of a Foley catheter. In the cases of intraluminal bleeding, an urgent endoscopy is essential in diagnosing and controlling the source of bleeding. Laparoscopic exploration is advised for the patient who presents with extraluminal bleeding with a sustained heart rate of more than 120 beats per minute and other signs of hemodynamic instability. Laparoscopic exploration allows for diagnosis but also therapeutic intervention with evacuation of the clots as well as surgical control of the source of bleeding if it is obvious with oversewing of the staple line. Many times the source cannot be identified, so evacuation of the hematoma and placement of a closed suction drain often help in patient resuscitation.

Staple line leak

Gastric leak is one of the most serious complications of laparoscopic sleeve gastrectomy; it occurs in up to 5% of patients. Based on upper gastrointestinal contrast study, gastric leak is classified into two types. Type 1 is a subclinical leak, which is controlled through a surgical drain, whereas type 2 is a clinical leak with diffusion of contrast into the abdominal or chest cavities.³⁹ Based on the timing of onset, leaks can be identified as acute (within 7 days), early (within 1–6 weeks), late (after 6 weeks), and chronic (after 12 weeks). The timing of the leak is strictly related to its etiology.⁴⁰

A patient with staple line leak can present with fever, tachycardia, tachypnea, or hypotension. In a study by Kolakowski and colleagues,⁴¹ the combination of clinical signs of fever, tachycardia, and tachypnea was found to be 58.33% sensitive and 99.75% specific for detection of anastomotic leak. Diabetes mellitus and sleep apnea were associated with a greater incidence of leak. Therefore, any patient who presents with signs and symptoms of anastomotic leak and unstable hemodynamics warrants diagnostic laparoscopy. In the presence of a leak, an abdominal washout and drainage with surgical repair if technically feasible are advised. Also placement of a feeding jejunostomy tube is indicated. Endoscopic modalities have also been successfully utilized in early leaks.

The treatment of a delayed gastric leak is more challenging, and surgical or endoscopic attempts to repair the leak are usually futile. The treatment options include placement of a living sump jejunal limb directly at the site of chronic leak, or a more radical laparoscopic excision of the fistula with Roux-en-Y esophagojejunostomy reconstruction.⁴⁰

Cholelithiasis

Routine cholecystectomy during bariatric surgery remains controversial. Weight loss following bariatric procedures is accompanied by a rise in the incidence of *de novo* gallstones formation of 38% to 52% in 12 months,^{42,43} but sometimes as early as 3 months postoperatively. Whenever the patient

presents with signs and symptoms of cholelithiasis, laparoscopic cholecystectomy is warranted.

The management of post-gastric bypass choledocholithiasis becomes difficult because of loss of endoscopic access to the duodenum. If the remnant stomach is anchored to the anterior abdominal wall, preferably with a radiological marker,⁴⁴ this may provide a safe point for percutaneous access to the stomach for endoscopic retrograde cholangiopancreatography (ERCP). A laparoscopic transgastric approach for ERCP has also been described.⁴⁵

BAND-RELATED COMPLICATIONS

Dysphagia

Immediate postoperative dysphagia is seen in some patients following laparoscopic gastric band, and this is usually due to excess perigastric fat resulting in a tightly fitting band or postoperative edema. Complete dysphagia, even to saliva, may take up to 10 days to resolve. Postoperative intravenous steroids and strict nil by mouth appear to increase the resolution rate for the edema and hasten recovery.

Band slippage

Slippage is defined as the cephalic prolapse of stomach through the band.²⁹ Slippage can cause complete gastric outlet obstruction, or even necrosis of the prolapsed stomach. A two-view barium swallow is the investigation of choice and is diagnostic. However, a plain radiograph is often sufficient to identify the horizontal position of a band after gastric herniation as opposed to its normal 45 oblique position in the anteroposterior view. Since the introduction of new techniques (pars flaccida technique) and new materials (low pressure larger volume bands), the incidence of acute band slippage has dropped to 1%–3%. If band slippage is radiologically confirmed, immediate deflation via subcutaneous port is required. The port may be difficult to palpate, but the patient is generally aware of its precise position. The most common positions are in the left upper quadrant, anterior to or just below the lower sternum or just lateral to the umbilicus. Band deflation should be performed under strict aseptic technique to avoid introducing infection into the band system. If this does not produce a rapid improvement in symptoms, then reoperation is necessary to avoid gastric ischemia. Patients may present with tachycardia and vague abdominal pain, investigations may show raised lactate level and acidosis, and these signs may indicate gastric necrosis, hence the need for urgent laparoscopic exploration. Laparoscopic band removal can be performed easily; usually there is a fibrous capsule around the band that requires dissection first, and the stomach wall may have been sutured around the band for fixation. Fulminant gastric necrosis should be managed by appropriate gastric resection after band removal.

Band erosion

This is relatively rare (incidence 4% or less) but can be a cause of bleeding, pain, or infection. Erosion of the band through the stomach is a slow process. The eroded band is exposed to gastric bacterial flora, and the tubing can become infected. One of the first signs could be recurrent infection around the access port. An alternative presentation is with weight regain as the band loses its restrictive effect. An eroded band is diagnosed either by contrast study or endoscopy or both. Removal of an eroded band can be done laparoscopically or endoscopically depending on the degree of erosion.

CONCLUSION

A basic understanding of the common bariatric surgical procedures being performed and their complications is necessary to safely and effectively manage the patients.

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Laparoscopic reoperative bariatric surgery

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INTRODUCTION

Bariatric surgery has been practiced for decades, but it became more frequent and popular by the combination of three main factors: the worldwide epidemic of severe and moderate obesity; the advent of laparoscopic surgery; and the acknowledgement by both physicians and surgeons that it is the single best method to achieve significant and long-lasting weight loss and have an impact in comorbidities and death risk. Thanks to its advantages of reduced pain, fewer wound complications, and faster recovery, laparoscopy has made bariatric surgery more attractive.

The exponential growth in the number of interventions all over the world, practiced by a larger number of surgeons, has the consequence of increasing the number of patients who will have unsatisfactory results and may require a new surgical procedure to change the outcome. Many experienced groups have practiced for a while not only primary but also reoperative bariatric surgery safely and successfully. They have found that causes of failure are diverse: The most common is insufficient weight loss, followed by metabolic complications, nutritional deterioration, and failures in gastrointestinal function or severe adverse effects that force both the surgeon and patient to make the decision to go back to the operating table.

Sometimes it is difficult to decide whether a patient needs an operation or can be treated nonoperatively, with a multidisciplinary approach that may be able to modify behavioral or anatomical situations and improve both outcome and quality of life. It is important to remember that a reoperation has a higher risk of complications, death, and even failure in correcting the problem for which the intervention is decided. When all reasonable and effective means have been exhausted and the patient's condition is not improved, surgery has to be considered.

This chapter reviews the situations in which bariatric operations that fail may require an intervention, first

describing the causes for each technique, then, the possible surgical interventions that can be carried out laparoscopically. It comments on the currently accepted techniques, mentioned in previous chapters, or the less common situations of patients operated with other techniques, in use but not proven, or currently not in wide use, that may require surgical treatment.

DEFINITIONS

For this chapter, reoperative bariatric surgery is considered as any surgical intervention that could be used to correct a problem arising from the first surgical procedure undertaken to treat morbid obesity. Those problems, complications, or adverse effects could appear early, within hours or days after surgery; but, some problems may take months or years to surface and become symptomatic. Some early situations may evolve into chronic complications.

How and when each independent condition is approached depends on the original operation, anatomical features, clinical manifestations, and general health status of a particular patient. Some complications, although similar in their origin, will have very different characteristics and behavior in different surgical techniques, and therefore, many will be treated as related to a procedure.

Having said that, the reasons why a surgical revision of a bariatric procedure is required may be placed in one of these groups: weight regain or insufficient weight loss, surgical complications, or altered gastrointestinal function,¹ and also can be added the emergency situations in the early postoperative period. This division may be somewhat artificial, since many situations may present as a combination of factors, or one may be the cause of another. This means that when defining a case in one of these three presentations, maybe another will appear as cause or consequence of the former.

Finally, and as pointed out by Ferraz et al.,² revision bariatric surgeries can be divided into conversion surgeries, for example, turning a laparoscopic adjustable gastric banding (LAGB) into an laparoscopic Roux-en-Y gastric bypass (LRYGB); surgery to adjust anatomy, like reconstructing a gastrojejunostomy in an LRYGB or redoing a dilated laparoscopic sleeve gastrectomy (LSG); or finally return surgeries, where, for example, a LRYGB is dismantled and normal anatomy restored. Again, it may be added as a group of emergency procedures, interventions made a few hours or days after the primary operation in response to an early complication.³

GENERAL CONSIDERATIONS

In all cases, it is important to follow certain steps in achieving all relevant information about the patient. If it is a patient from the group, past history, follow-up, and previous investigations need to be reviewed. If the patient was lost to follow-up or is coming from outside the group, a new and complete history, including investigations, needs to be done. Full studies are completed, from nutritional status, to the current state of comorbidities, to prepare the patient as well as possible for the operation. Finally, full support from the multidisciplinary group needs to be organized all through the preparation, surgery, and postoperative periods, with psychological counseling. This last will assist the surgeon in clearly and thoroughly explaining to the patient and his or her family the exact characteristics and seriousness of the condition; why the operation failed; the decision to operate based on the information obtained and its goals; and finally, the higher risk of a second operation, including new failure or complications and death.

When surgical treatment has been decided, the imaging and endoscopic studies are used not only to establish the cause and severity of the failure, but importantly to create a map of the condition, a clear anatomy of the primary operation and the present complication, allowing the surgical team to plan the procedure and possible alternatives.

Absence of weight loss or insufficient weight loss

Weight regain can be defined as the situation when a patient recovers 15%–20% from the lowest weight obtained after a bariatric surgery.^{4,5} Insufficient weight loss is present when the patient does not achieve a minimum loss of 50% of the excess weight. This last definition is based on the widely accepted notion that a successful operation achieves at least 50% of excess weight loss.³

RISK FACTORS FOR WEIGHT REGAIN AFTER BARIATRIC SURGERY

It is a fact that a very high proportion of bariatric patients, after reaching their minimum weight (nadir), have a small regain. This situation has been considered acceptable by

most groups, as long as it does not progress—that is, weight regain does not reach 15% or more.⁶

Many and very different circumstances can produce weight regain important enough to require treatment,⁷ such as use of certain medications, hormone-related issues, and sometimes for reasons that cannot be explained. However, more often the cause is behavioral (eating habits, depression, and lack of exercise); this is when many times, as Kellogg graphically describes it,⁸ it is the patient who failed the operation and not the other way around. There are also situations that are more likely to require surgery. There are some associated with the surgical technique, like a very wide gastrojejunostomy stoma of an LRYGB or a large gastric pouch in LAGB, LRYGB, or LSG; some are related to a surgical complication, like gastrogastroic fistula in LRYGB (due to a complication or incomplete division of the stomach); and some are caused by changes in the anatomy of the operated stomach—gastric pouch dilatation in all techniques or enlarged gastrojejunostomy in LRYGB.

Remnant stomach dilatation can appear after surgery; however, it is sometimes a technical mishap when the pouch is left larger than desired. It can happen in LSG, LAGB, or LRYGB. It is important to note that it can be overlooked initially, because the strict diet and initial supportive follow-up may achieve the expected weight loss, but after a while, when diet is relaxed and the patient realizes that he or she can eat more, or if follow-up is abandoned, then weight regain is a real possibility.

The importance of weight regain cannot be overstressed, since it is arguably the most important cause of failure of bariatric surgery. It might be overlooked because patients tend to slip from follow-up, and surgeons may not perceive it as important in their practice. Patients who abandon counseling of a bariatric group start eating more and may stop exercising; consequently, the anatomical modifications created start to dilate and patients regain weight. If anxiety and depression were part of the patient's condition, they reappear, and the circle is complete.

NONOPERATIVE TREATMENTS AFTER WEIGHT REGAIN

The main goal of postbariatric surgery follow-up is to ensure patients lose weight according to expected rates and do not regain it. Long-term studies show a certain degree of weight regain around the second postoperative year,⁶ and in approximately 20%–30% of them it can be substantial, indicating a failure of the surgical procedure.⁹

When a patient regains weight, whether or not he or she has remained in the program, the first and most effective intervention is a structured follow-up adjusted to patient needs with his or her commitment to the program.^{10,11} The best results have been obtained by working in a multidisciplinary group with nurse, dietitian, and notably, a specialist providing psychiatric or psychological management and support. Such an intervention, providing the surgical procedure followed the proper technique and no complications occurred, may be successful, and no other treatment may be required.¹² In any case, parallel investigations need to be conducted in order to establish if there are other possible

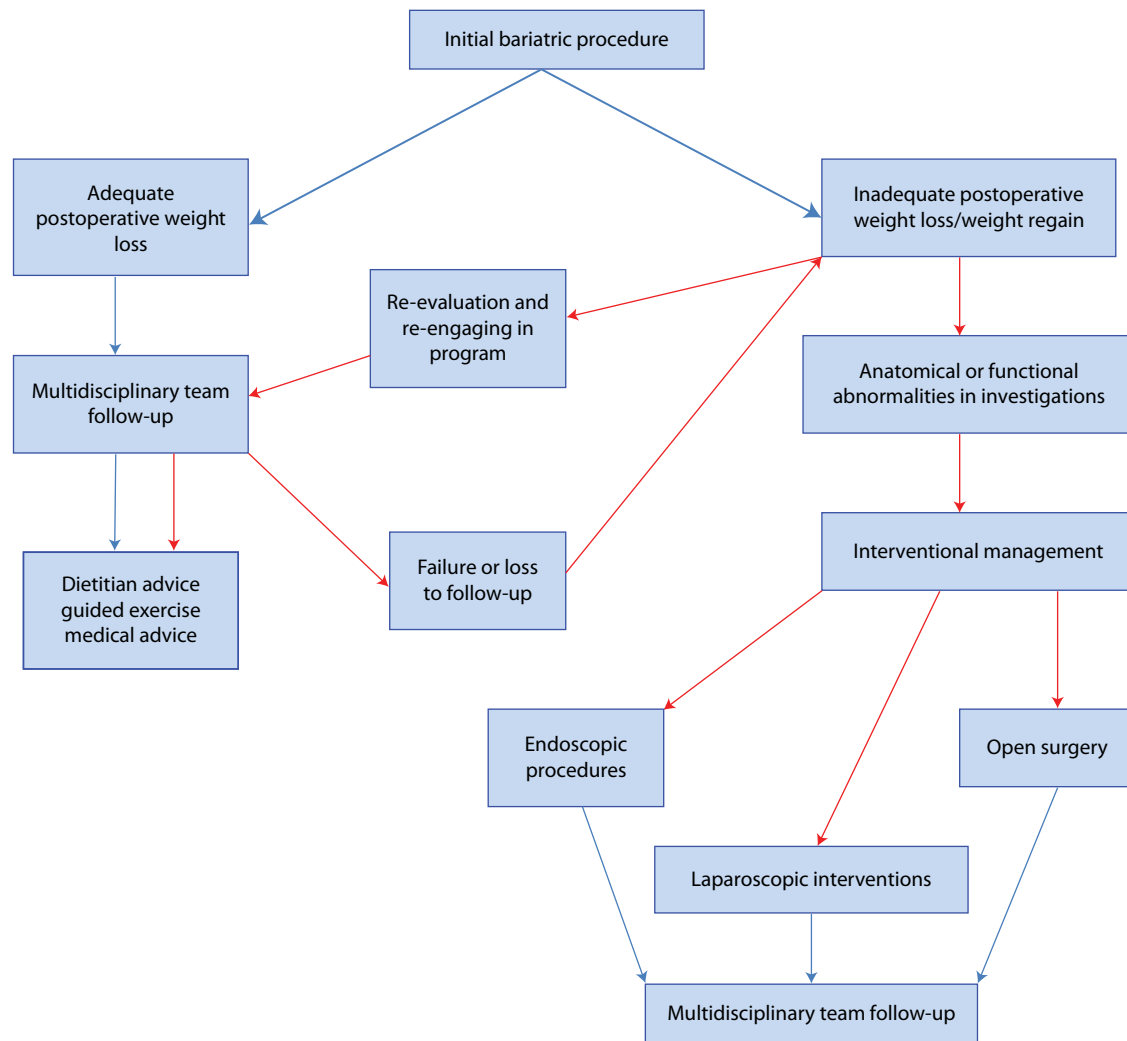


Figure 67.1 Flowchart: management of weight regain or insufficient weight loss. When a failure is detected (red arrows) the patient should be placed in close follow-up and nonoperative management. If it fails or anatomical failure is found, an intervention should be planned.

causes and if other treatment may be required. The follow-up process, including how to manage a patient with weight regain is presented in [Figure 67.1](#).

INDICATIONS OF SURGICAL TREATMENT FOR WEIGHT REGAIN

When an anatomical or functional complication is associated with weight regain, or in the case other interventions do not work after a reasonable period of time, it could be necessary to consider a revision. Since this chapter is specifically about laparoscopic revision, other possible interventions are mentioned when appropriate, only to put both surgical and other therapies in perspective and to state the indications according to the best available evidence.

It is worth remembering that a new operation has a higher risk, due to scarring, adhesions, the presence of inflammation caused by fistula, or other complications. Bariatric reinterventions tend to be longer, bleed more, and have a prolonged in-hospital stay plus a higher risk of complications.¹³

Additionally, it may not produce the expected results in terms of weight loss. As mentioned before, new technological advances allow for endoscopic interventions to be carried out in certain complications, with the risk reduction associated with a less-invasive intervention.

The decision of what surgical treatment is to be used depends on the mechanism of weight regain. This mechanism needs to be clearly defined using any investigations required: endoscopy, contrast imaging, and blood tests.

Laparoscopic Roux-en-Y gastric bypass

The main cause of failure in LRYGB in terms of weight loss is the failure of the restrictive mechanism, considered its main weight control characteristic. A dilated pouch or a dilated gastrojejunal anastomosis causes the failure.

A large gastric pouch can have two origins¹⁴: first, the reservoir was too large from the start, but its presence was concealed by the weight loss produced by the very strict initial postoperative diet and multidisciplinary team follow-up.

Once the most demanding stage ends, the patient starts eating to the full capacity of the pouch, regaining weight. If the pouch construction is horizontal rather than vertical, or if part of the posterior wall of the stomach remains, a larger and more elastic pouch is present, thus allowing for a higher chance of dilatation. When present, this technical error or failure is related to lack of experience or to super obesity. In both situations, the posterior fundus is not well exposed, and to avoid a complication, the surgeon leaves a larger pouch¹⁵ due to incomplete assessment of the anatomy. The second mechanism is related to the size of the gastrojejunal anastomosis. The stoma may be small due to inflammation, stenosis, or because it was constructed too small from the beginning. In the long run, a narrow stoma produces pouch dilatation. Additionally, if a gastrogastic fistula is present or suspected, it may increase the ingested volume. Ianelli et al. resected the excessive pouch segment, sometimes with reconstruction of the anastomosis.¹⁵ With this technique they achieved good weight loss, the downside being a higher risk of conversion and complications. However, it has been criticized for the low weight loss reached and the poor ratio between success in reducing weight and the risk involved.¹⁵ A plication of the gastric pouch has also been proposed,² but no comments are possible at this time, since only a few patients have been treated with it.

As for the second mechanism, if an excessive amount of food passes through the gastrojejunal anastomosis, the effects of early satiety and restriction are lost, and the patient gets to eat more and regain weight. Using a logistic regression model, a correlation between the stoma diameter and weight in LRYGB patients has been found.⁵ Authors employed a flexible probe to measure the diameter of the anastomosis and followed patients endoscopically measuring the stoma diameter and their weight (Figure 67.2). During the 5-year follow-up, the wider the anastomosis got (every 10 mm), the greater was the weight regain. Therefore, a wide anastomosis in a patient who is doing well is a risk factor for weight regain.⁵

Several authors have suggested that surgery is indicated when the stoma diameter is superior to 30 mm.^{2,3} The technique that corrects a dilated stoma is the surgical creation of a new gastrojejunal anastomosis, a more complex operation that carries considerable risk, since the dissection of scarred tissue makes the procedure more laborious. The intention is to use normal jejunum in the redo anastomosis. There is another technique that can simultaneously reduce pouch size and stoma diameter, by stapling across the enlarged Roux limb stump, the gastrojejunal anastomosis, and the oversized gastric pouch, as described by Fingerhut et al.¹⁷

The gastrogastic fistula is another form of restriction loss, caused by communication between the gastric pouch and the abandoned stomach.¹⁸ It is probably produced by complications like anastomotic leaks, marginal ulcers, pouch perforation to the gastric remnant, or foreign body erosions, although the etiology is still unclear. As for surgical technique failures, there is the incomplete division of the stomach. It presents as postprandial pain, followed by

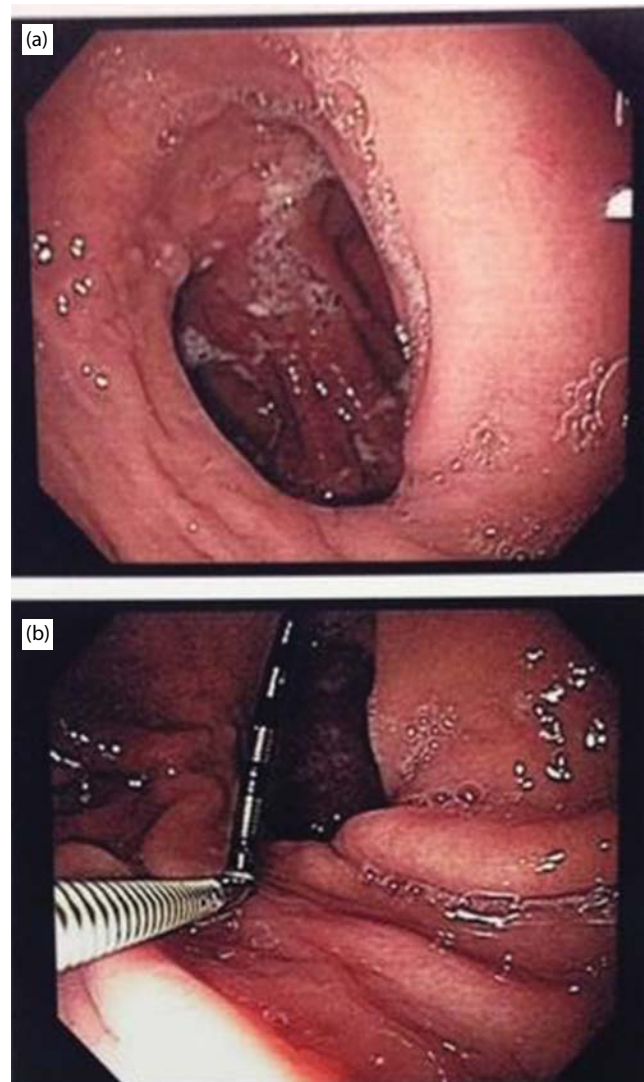


Figure 67.2 (a) A stoma so enlarged that both limbs of the anastomosed bowel can be viewed. (b) The probe used to measure the diameter of the stoma. (Courtesy of Dr Galvao Neto, with permission.)

nausea and vomiting, and of course weight regain. To decide the operation, endoscopy and contrast x-rays are practiced. The first may show the communication and its ulcerated edges, and the latter, the presence of contrast in the abandoned stomach. The surgical procedure may be the sole division of the communication, but a more definitive procedure, the remnant gastrectomy, has shown good results in initial experience,¹⁸ and a 2015 report suggests good results in a small number of patients after a tailored approach according to symptoms.¹⁹

Laparoscopic adjustable gastric banding

Although still practiced in the United States, LAGB is almost abandoned in Europe and Latin America.²⁰ Weight regain is very frequent, and the device is also associated with a high rate of complications. In North America, surgeons

are coming to understand and experience those downsides in their patients.²¹

After being removed, there is a fibrotic surface where the band was that needs to be removed. If there is no partial or complete penetration of the band into the stomach wall, conversion to another procedure can be done immediately, but if tissue inflammation was severe and the stomach thickened by it, a second stage can be reserved for the new procedure. What intervention is practiced will depend on previous weight behavior. One case is the patient who had a successful weight loss and after a while regained it, therefore proof that restriction actually worked in him or her, but a dilated reservoir produced the failure. In this case, it would be acceptable to convert the LAGB to another restrictive procedure, specifically LSG.²² If the patient never lost enough weight, an LRYGB can be performed.

LAPAROSCOPIC SLEEVE GASTRECTOMY

Weight regain after LSG is usually explained by a dilatation of the tubular stomach (**Figure 67.3**). The larger stomach can be explained by the same reasons described for the LRYGB: it was left too large from the beginning after using a large bougie or because a large portion of the posterior fundus was overlooked at stapling. Also, abandoning the diet can lead to dilatation even with a well-constructed sleeve. If the

patient starts regaining weight right after the initial liquid diet is stopped, and does not reach the goals, the cause may be a large stomach left in situ. Since very early in the technique's introduction, a re-sleeve has been used to improve weight results, a goal that has been arguably achieved in the initial follow-up.²³

If weight regain or insufficient weight loss are not related or if the studies do not show an anatomical defect on the sleeve, or if there are complications related to the technique, the recommended surgical treatment might be an LRYGB or a duodenal switch.

OTHER PROCEDURES

There are other less frequent interventions that can fail producing weight regain. Vertical banded gastroplasty was described by Mason in 1982²⁴ and practiced frequently in the United States in the past. It can have a failure of the band, caused by disruption. A larger amount of food will pass at a higher speed, with the loss of restriction. The other possible mechanism is a gastrogastic fistula. In many cases of open surgery, the stomach was only stapled and not divided, and with time, the stomach would reopen, bypassing the band.

When the gastric plication suture lines fail, the stomach reopens partially or completely, producing a larger intragastric volume. It is a proven fact from older bariatric surgical techniques and their variations that sutures and clips fail with time in the stomach unless it is divided.²⁵

ENDOSCOPIC TREATMENT OF WEIGHT REGAIN

Although proposed several years ago,²⁶ this approach is only recently having an impact with technological advances and new techniques in endoscopy. The advantages are that it is a nonsurgical approach, avoids dissection in inflamed and scarred tissue, and interventions can be repeated. It is also ideal in high-risk patients.

Successful gastrointestinal anastomosis size-reduction (TORe) has been achieved using devices adapted to modern scopes to practice endoscopic suturing.²⁷ Adding argon plasma burns to the surface to be sutured reduced the risk of recurrence, although recent reports suggest that argon plasma alone can successfully reduce the size of the anastomosis.²⁸ In LSG pouch dilatation, endoscopic plication has been tried. However, the small number of patients only allows for considering it promising but still unsupported by evidence.

Surgical complications or altered surgical anatomy

After a bariatric operation has been carried out, most patients have a clinical outcome within what is reasonably expected. Some of them may have variations in pouch size, anastomosis configuration, stoma size, sleeve shape, and lumen in contrast imaging, among other differences. This is true even when the same surgeon has carried out the operations. In fact, when surgeons meet and compare their techniques, there are differences within the same procedure that may

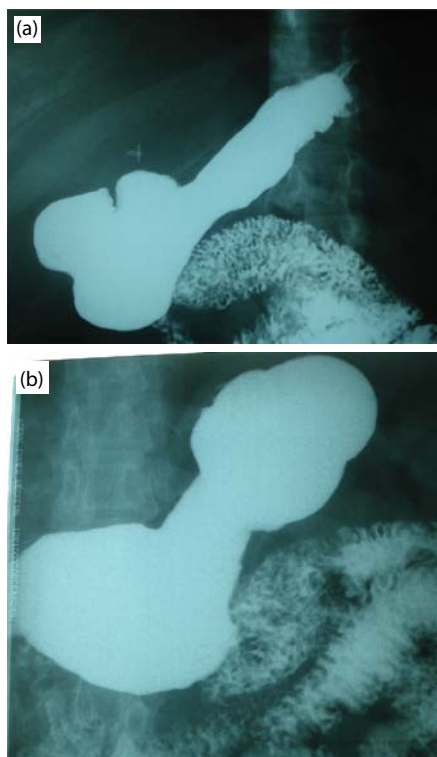


Figure 67.3 Contrast x-ray of a female patient with a sleeve gastrectomy that was left too large from the beginning. (a) The whole sleeve is large, and the antrum is untouched. (b) A different projection exposes a large posterior fundus left inadvertently.

render different results from the anatomical point of view, but outcomes are often comparable. However, sometimes the final result of different operations is not the expected, and at some point in the postoperative period, usually with progression to a definitive diet, patients start experiencing symptoms that indicate the presence of a complication, or at least an unwanted effect of the procedure. For some patients, years may pass to develop the actual complications that can affect the patient's condition to a point that an intervention, surgical or not, is required. Only a thorough clinical history and appropriate studies will help decide if treatment should be endoscopic, surgical, or not necessary.

CAUSES

Laparoscopic Roux-en-Y gastric bypass

Reviewing the gastric bypass literature, several variations tried along its almost 50 years in existence can be found. It might be banded or nonbanded, and it may still be possible to find patients with nondivided remnant stomachs from the pouch.²⁹ And as techniques are different, consequently, complications may vary.

Stoma ulceration can have different causes and is frequently accompanied by other anatomical problems, especially stenosis.³ It is associated with dysphagia, vomiting, chronic pain, and malnutrition. If developed early in the postoperative period, stenosis can lead to fistula formation. High pressure and inflammation may lead to ischemia in areas of the staple line, creating a disruption and leakage of gastric contents. An abscess formed from this accumulation of fluid will try and find a low-pressure tract to the exterior or to another organ, forming a fistula.

Another possible finding is a gastrogastic fistula. This complication has different mechanisms, initially the cause was the use of a staple line without cutting the stomach as it was done in the beginning of gastric bypass. In these cases, the staple line fails frequently, and a connection between the gastric pouch and abandoned stomach is partially restored. Capella³⁰ showed how surgical technique was paramount in reducing its incidence from near 50% to almost none. They demonstrated that it was very frequent in undivided gastric bypass, less so when the stomach was divided and stapled, and how it dropped under 6% when the jejunal alimentary loop was placed between the two parts of the stomach. Therefore, after an LRYGB with division of the stomach, gastrogastic fistula has been described in relation to reintervention, gastrojejunal anastomosis, fistula, or marginal ulcers.^{31,32} where inflammation and even infection may produce a communication between the pouch and the remaining stomach.

There is one form of gastrogastic communication that should not be called "fistula," although its anatomy and behavior are almost identical: the inadvertently incomplete division of the stomach. Surgeons are more prone to fail in completely transecting the stomach to create the pouch if inexperienced, or in the presence of previous upper abdominal surgery, or in a superobese patient.³¹

Laparoscopic adjustable gastric band

The band can alter the anatomy or have complications that can compromise quality of life, with several important examples recorded. Prosthesis erosion is caused by chronic inflammation of variable duration. Being such an active and dynamic region, the esophagogastric junction and the cardial region of the stomach are in constant movement and the presence of a foreign body wrapped around the stomach are combined to produce friction, pressure, and distension, therefore generating inflammation. In time, inflamed tissue is eroded by the moving foreign object, and the band moves into the stomach lumen until it is found completely inside the stomach, so much so that the connecting stalk can be cut and the band extracted endoscopically.²⁹

There is also band slippage when the band moves from the ideal position where it was supposed to be left and fixed by the surgeon. It can produce an hourglass-shaped stomach with the risk of ischemic necrosis and perforation in case of an acute presentation. It is often associated with a failure in surgical technique.²²

Laparoscopic sleeve gastrectomy

If a narrow sleeve is created and at a point it angles or bends on itself, a situation called *kinking* is present. It usually happens in relation with the incisura angularis.³³ According to Cottam et al., kinking is independent from the bougie size but correlates with oversewing of the staple line rather than with sleeve diameter.³⁴ The acute angle previously described may reduce the lumen in a specific spot, where food starts to pile up. The mechanism by which oversewing of the staple line causes kinking is if a stitch that inadvertently goes too deep and through the lumen reduces it, or if placed too far from the previous stitch, when tightened, the sleeve wrinkles and bends.²²

Another cause of reduction of the sleeve's internal diameter is a real stricture. It tends to be chronic, and developed in a longer course, caused by ischemia of the pouch, retraction due to scarring, fistula, or inclusion of the esophagogastric junction in the stapling line.³⁵

Severely altered gastrointestinal function

When there are gastrointestinal symptoms that severely alter the ability of the patient to eat comfortably and in sufficient amount as to maintain a good nutritional status, or if a condition that presents repeatedly generates pain, discomfort, or an additional pathology, the patient may require surgery. These are situations that severely compromise the patient's quality of life, but as they may be progressive, the patient will adapt to them. He or she may not recognize them as complications after a while and will not complain about them, for example, changing diet from solid, to soft, and then to liquid in progressive dysphagia, or staying at home due to diarrhea or gas.

One potentially serious consequence of restrictive procedures is gastroesophageal reflux disease (GERD).^{1,8} It may be present previous to the operation, or appear *de novo*. It becomes a problem or worsens with the creation of the high-pressure system typical of restrictive procedures like LSG, LAGB, and vertical banded gastroplasty (VBG).²² Pain, dysphagia, and heartburn that are difficult to control may be present, and when esophagitis is objectively demonstrated by endoscopy, a reintervention could be required.

EMERGENCY SITUATIONS

In the first postoperative hours or even days, there may be emergency situations that require an operation, and they may be some of the conditions discussed above. Examples are listed in **Table 67.1**. Before the surgical treatment of the other three groups of complications is discussed, these situations are described here, and the intervention is mentioned since these are special conditions that need more direct and decisive treatment.

Bleeding is a possible complication of any surgery, but in bariatrics, wide dissected surfaces, portions of the stomach or bowel cut, and long staple lines are sources for it. To prevent postoperative bleeding, a thorough visual examination of vessels cut and stapler lines is mandatory after completing the procedure, to make sure no active bleeding is present. If a bleeder is found, the surgeon can use clips, a suture tying it or energy where safe. In a small percentage of patients, there will be bleeding. It can be intra-abdominal or to the gastrointestinal tract and limited or continuous.¹ If limited, transfusion may be enough. If evidence of unremitting bleeding or excessive pain related to it is present, surgery should be the treatment. The decision to take an open or laparoscopic approach depends on the condition of the patient. Another problem related to bleeding is the formation of hematomas. The authors described obstruction of a sleeve by a posterior hematoma pressing and blocking food going through and causing vomit.³⁵ The reintervention's aim is the removal of the largest amount of blood and clots possible. Many times the exact point of origin is not found, but if there is a suspicious vessel or staple line, it should be treated. Rarely, gastrointestinal bleeding needs endoscopic treatment.

Acute cases of obstruction can have different origins: kinking of the sleeve in LSG or the jejuno-jejuno anastomosis in an LRYGB gastric mucosal edema or external compression.³⁵ A patient who early in the postoperative period

presents with vomiting or salivation may have some kind of obstruction. If an upper GI series is done, it may show contrast accumulated in the point of obstruction or not progressing, or contrast may trigger vomiting or dysphagia complaints.³⁵ Stopping oral intake, maintaining hydration, and observing the patient may be enough to have resolution of obstruction in an edematous gastric outlet or anastomosis or a sleeve.³⁶ However, if other symptoms like tachycardia are present, or if investigations are abnormal, waiting may produce deterioration, and more serious conditions should be ruled out.

Endoscopic management and the use of stents have been described^{35,37} and are out of the scope of this chapter. Surgical treatment is the last resource, but it should not be spared in case of need, and as in other laparoscopic procedures, decision-making should be swift and aggressive in early presentations. A new diagnostic laparoscopy may show the kind of situations that require surgery. In case of an obstructing or compressing hematoma, all abnormal content is removed. If a staple line has been oversewn, stitches placed too far apart will produce a wrinkle that may cause obstruction and/or kinking. In a gastrojejunostomy of an LRYGB, a suture could inadvertently close the anastomosis and produce a severe and life-threatening obstruction. As pressure builds, damaging effects are produced both in tissue and in stapler or suture lines. Cutting those technically faulty stitches will reduce pressure, ischemia, or obstruction.³⁸ If kinking of a different origin presents early, reintervention through fixation of the angulated incisura and the fundus may solve the problem.³³ Intraoperative endoscopy is useful, since it may reveal the cause and show how the intervention is effective immediately, if, for example, a stitch going through the gastric lumen is seen being removed, restoring the normal aspect of the sleeve, pouch, or anastomosis. Either by some of the complications mentioned above, or by the lesion of the vasculature, acute ischemia and necrosis of the gastric pouch might appear after LSG or LRYGB. This condition may require total gastrectomy.³⁹ Other causes of acute obstruction are internal hernias or port hernias, both requiring rapid responses. Since this obstruction is typically more distal, it can affect any of the anastomosis in an LRYGB, as well as the vascular supply. Most times, these are easily treated by an early laparoscopy.

Acute leaks and peritonitis are feared complications that require high suspicion levels and rapid intervention.²² Leaks appear mostly within the first 5 days, more commonly at the gastrojejunostomy of a LRYGB,¹ although they can appear after an LSG.²² Ischemic tissues after dissection, obstruction, or technical failures of the staple line or sutures are possible causes. Also, an inadvertent bowel perforation cause by manipulation can be blamed. Although a rare occurrence, it should not be forgotten that the stapler could tear the bowel during manipulation, often at blind spots. Therefore, careful manipulation of the stapler and visual confirmation of its position are required to prevent these lesions. Removal of membranes and location and

Table 67.1 Acute complications requiring emergency surgery

1. Acute obstruction: Edema of gastric lumen or anastomosis, kinking
2. Hematoma/acute bleeding
3. Acute unresponsive pain
4. Acute leakage
5. Peritonitis

repair of the leak are the actions required to solve the problem. Intraoperative identification of the disruption is made using methylene blue, air insufflation, and on occasion, endoscopy. Once found, a thorough repair with stitches is conducted and a closed drainage is left. Antibiotics and closed follow-up are started.

SURGICAL TREATMENT

Considerations for surgery

It is paramount to remember that the procedure will be challenging, long, and require skill, patience, and attention to detail. Several things need to be kept in mind⁸: although upper GI contrast studies, computed tomography scan, endoscopy, and other tests are of great help and are required to decide on surgery and plan the procedure, many times clinical judgment is put to a test if there is an unexpected finding. Therefore, plans may need to be changed to achieve the best possible result. This means the surgeon must have experience in reoperation, or should seek the support of a more experienced colleague to carry out the operation with him or her. Additionally, intraoperative findings can be unanticipated even after a careful study. Sometimes, when no previous written clinical records are available, the only reference is the patient's personal account of having a bariatric operation, for example, "the band" or "stomach stapling," 20 or more years back. Even with the surgical notes, some descriptions may not be clear enough, and a banded procedure could have very different materials wrapping very different parts of the gastric reservoir or anastomosis.

There will be adhesions that will need to be divided even to achieve the insertion of the first port. An open technique or an optical trocar should be used.²² Adhesions division is carefully conducted, ideally with scissors to avoid cautery damage and further inflammation. If too severe, they may prevent the use of small bowel for LRYGB or biliopancreatic diversion with a duodenal switch (BPD-DS).

When dividing the stomach, the use of large staplers (4.1–4.5 mm) reduces the chance of leaks, since inflamed tissue in relation with a complication or scars from previous anastomoses may suffer necrosis or tears with smaller staplers. Additionally, the staple line should be reinforced with the preferred technique.⁸ After the operation has been completed, it is necessary to test suture and stapler lines for leaks. Careful hemostasis is carried out, and any contamination is washed out. Pneumatic or methylene blue tests and contrast imaging will help rule out any acute problem.

As these are complex operations in scarred tissue in patients with comorbidities or complications that can affect the outcome, complications like leaks, intra-abdominal abscess, bleeding, and wound infection may occur.³ Initial follow-up should also be directed to rule them out, as clinical manifestations may be subtle.

Reintervention after vertical banded gastroplasty

Once adhesions are removed, anatomy of the wrap is clear, and the band is identified, it is cut open to be removed. Silastic bands form a fibrotic tunnel around them that makes removal less difficult. Polypropylene meshes may be integrated in the surrounding tissue or even erode the walls in the direction of the gastric lumen.¹ Fibrotic tissue should be removed to avoid strictures. If the patient was taken to surgery due to GERD, dysphagia, malnutrition, or pain, the operation may end here. However, sometimes to create a large enough stomach a gastrogastrostomy is required.⁴⁰ If the issue was weight regain, another procedure should be practiced. LSG has been described but is not supported²² due to the risk of stenosis. A more widely accepted procedure is LRYGB.³ The gastric pouch is created above the place where the band was removed to avoid stapling over scarred and inflamed tissue. As described elsewhere, the authors recommend placing a gastrostomy in the defunctionalized stomach.⁸ Also, a laparoscopic BPD-DS could be decided.

Reintervention after laparoscopic adjustable gastric banding

As in VBG, the band is removed and the fibrotic tissue cut to avoid stenosis. After that, most of the times a new bariatric procedure is conducted. If excessive inflammation or bleeding were present, if there is a complication, or if the patient is displaying problems related to anesthesia, blood loss, or prolonged operating time, the procedure can be stopped at this point. If this is the case, a redo bariatric is planned as a second stage, after the patient has recovered. If not, the operation is completed as planned. An LSG can be a good option if the patient had a good weight loss and the failure of the operation is caused by other factors.²² However, if severe reflux, esophagitis, or esophageal dilatation are present, the best choice is an LRYGB. But, if insufficient weight loss is the cause, the alternative can be LRYGB or a BPD-DS. As mentioned before, appropriate-sized staplers are used to avoid tears, leaks, or bleeding. It is advisable to reinforce staple lines and to test the sutures and staple lines by the preferred method to make sure there are no leaks.

Reintervention after laparoscopic Roux-en-Y gastric bypass

Since over the years gastric bypass has had several modifications, nothing can be assumed, even knowing the operative notes of the index operation. There may be variations in pouch size and direction (vertical or horizontal), anastomosis shape and position, and location of bowel in relation to the stomach and transverse colon. Additionally, a band may be present in some patients. Gastric pouch, gastrojejunostomy,

and the alimentary limb all the way to the jejunum-jejunostomy should be exposed, and anatomy must be clearly identified before any resection is carried out.

In the presence of malnutrition or severe vitamin or mineral deficiencies, intractable vomiting, chronic pain, or recurrent ulceration, among other causes,¹ it is possible to laparoscopically reverse the gastric bypass and restore normal anatomy. This is done, of course, at a price in terms of operative time and risk of complications.

Insufficient or absent weight loss can be treated with gastric banding of the pouch, improving the weight loss and significantly reducing the body mass index (BMI).⁴¹ A band over scarred tissue might be a factor for erosion. One cause of weight regain, pain, and other associated problems is a gastrogastroic fistula, for which the division of the fistula with or without resection is the appropriate treatment. If an enlarged anastomosis is to be blamed, a redo gastrojejunostomy of an adequate diameter should produce the expected results. Cutting and stapling the anastomosis without gastric resection may be enough in some cases; however, many times a dilated pouch is part of the problem. In this case, the pouch is remodeled, and the anastomosis is created using healthy and unscarred bowel.⁸ It is now possible to endoscopically remodel both the pouch and the gastrojejunostomy using suturing devices.²⁷ Long-term results are still not available or conclusive.¹ As opposed to improving restriction, obtaining more malabsorption has been attempted by creating a longer Roux limb and a shorter common channel by moving the site of the intestinal anastomosis. Risks of this approach include complications such as intractable diarrhea, malnutrition, and anemia.⁸ A few groups have advocated conversion of LRYGB to a BPD-DS.⁴² This means restoring the stomach and pylorus and creating several new anastomoses, all in a difficult surgical field. There is still limited evidence for any of the methods mentioned above in redo operations after LRYGB.

Finally, fistulas tend to close with sepsis control, bowel rest, parenteral nutrition, and management of obstructive or inflammatory conditions that can produce or perpetuate the leak. If this management fails, surgical closure and removal of the associated factors are carried out.

Reintervention after laparoscopic sleeve gastrectomy

With its increasing popularity and initial lack of standardization, LSG is presenting with failures and complications that require additional treatment. Dilatation, fistula correction, stenting, and pouch reduction can all be done laparoscopically, some with proven good results, some still waiting for long-term evidence.

A frequent problem associated with LSG is GERD. Most of the times it is self-limited, disappearing after weeks with medical treatment. However, it may persist and become serious with the risk of developing associated

complications like stenosis and Barrett esophagus. Currently, most groups look for hiatal hernia and correct wide hiatus to prevent it. If surgical treatment is required, conversion to LRYGB or BPD-DS is a good option.^{3,22} If weight regain is present, as previously mentioned, a large fundus left behind or sleeve dilatation may be the cause, and a re-sleeve may be enough if good follow-up and support are obtained. Conversion to the above-mentioned procedures may be the best way of achieving adequate excess weight loss.

In case of an intractable stricture, it has been reported that a stricturoplasty, as practiced in inflammatory bowel disease, is possible and has had good results.⁴³ Also, Roux-en-Y gastric bypass may be practiced in these cases, resecting the remaining stomach including the stricture, and creating the anastomosis as the technique requires.¹ Sometimes, a total gastrectomy is the only way of solving the problem definitively.

Dapri, Cadiere and Himpens have reported in patients with long stenosis approximately 10 months after LSG and in patients considered not eligible for endoscopic balloon dilation, a laparoscopic seromyotomy.¹⁶ Results were satisfactory in this small series, with resolution of symptoms including GERD and adequate anatomy on barium swallow.

Fistulas are closely related to stenosis and may appear in poorly irrigated parts of the staple line, generating a leak to relieve the pressure. Usually the best treatment is the resolution of the stenosis, or even pyloric balloon dilatation with a stent placed at the leak. However, persistent leaks may require surgical closure, or in severe cases, as in stenosis, resection of the involved segment with conversion to an LRYGB or a gastrectomy.

CONCLUSIONS

1. A complete study of clinical history and investigations is required to decide if the treatment is observational, endoscopic, or surgical, what approach should be employed, and what bariatric intervention will be carried out.
2. The decision of what surgical procedure is used depends on the technique employed the first time, the cause for reintervention, the initial weight loss, and the current condition of the patient as defined in clinical history, examination, and investigations.
3. The final approach can only be decided according to intraoperative findings, and surgeons need to be prepared to change the course of action during surgery when facing unexpected findings, and they should have devised alternative plans.
4. Patients need to be informed of the higher risk and potentially less successful results after a reoperative bariatric surgery.
5. The urgency of early complications needs to be decided fast to avoid ominous results as a consequence of delayed intervention.

6. Reoperative bariatric surgery is complex, time consuming, and plagued by complications that make it a field for experienced surgeons.

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Video-assisted thoracoscopic vagotomy for marginal ulcers

CAROLINE PARK AND SIDHU GANGADHARAN

BURDEN OF DISEASE

Despite advances in medical therapy, peptic ulcer disease continues to have considerable presence in patient care, with an estimated incidence ranging from 20 to 60 per 100,000 in the United States.¹⁻³ Peptic ulcer disease also carries a significant global burden and remains one of the most common causes of death in the world⁴ with a mortality estimated to be between 5% and 10% for bleeding complications.⁵ Its treatment brings considerable tangible cost, creating an estimated 1 million hospitalizations and 6,500 deaths per year and annual health-care costs approaching \$6 billion.⁶⁻⁸

HISTORY

Often considered a subset of peptic ulcer disease, marginal ulcer disease, which is generally considered to be an ulceration of the gastrojejunal anastomosis, and its treatment have been well-described since the early 1960s.⁹ Patients with recurrent and/or medically refractory peptic ulcer disease historically underwent a spectrum of selective vagotomies without antrectomy and were found to have increased recurrence up to 12% with highly selective vagotomy.¹⁰ Multiple permutations of subtotal gastrectomy with ranges of selective vagotomies were performed in the next few decades, with antrectomy and vagotomy generally demonstrating the lowest rate of recurrent ulcer at less than 1%.¹¹

The introduction of endoscopy in the last two decades has paralleled a concomitant increase in the prevalence of marginal ulcer disease given its widespread use and broadened indications. And with the advent of weight loss surgery, particularly Roux-en-Y gastric bypass and sleeve gastrectomy, marginal ulceration and staple-line ulceration have become an increasingly more tangible, difficult problem to

treat with medical and surgical measures. The incidence of marginal ulcer varies widely within this particular subset of patients undergoing weight-loss surgery, ranging from 4% to 12%.¹²⁻¹⁵

RISK FACTORS

The risk factors for marginal ulceration essentially mirror that of peptic ulcer disease, which historically included older age, steroid use, prolonged hospitalization,¹⁶ smoking, and nonsteroidal anti-inflammatory drug (NSAID) use.¹³ Follow-up studies of patients who previously underwent acid-reducing surgery and re-presented with recurrence of symptoms were more likely to have incomplete vagotomies and NSAID and aspirin use.¹⁷ Among patients status-post-Roux-en-Y gastric bypass in the early 1990s, those with increased pouch-length and staple-line dehiscence were at higher risk for marginal ulcers.¹⁸ Multiple subsequent studies have found additional risk factors, including diabetes and long gastric pouches, with the proposition that increased acid exposures and ischemia lead to ulcers.¹⁹⁻²²

INITIAL WORKUP AND MANAGEMENT

Marginal ulcers can present at any time, from months to years after surgery. A thorough assessment of the patient includes a detailed history intake including NSAID use, smoking, symptoms of nausea, vomiting of blood or bile, and abdominal pain; physical findings are variable, with epigastric or generalized abdominal pain. In the acute setting, such as with perforation or bleeding, the patient requires adequate resuscitation and stabilization with close monitoring. This includes prompt intravenous (IV) access,

fluid administration, and confirmation of blood product availability in the case of bleeding.

Only a few decades ago, histamine receptor blockers were championed as the mainstay of medical therapy for recurrent ulcers, though nearly 50% of patients required definitive surgical intervention.²³ With the advent of endoscopy and the armamentarium of tools to locate and constrict, seal, or clip visibly bleeding ulcers, many of these patients are now treated conservatively with close hemodynamic monitoring and IV proton pump inhibitor therapy.²⁴ Patients are eventually stabilized with close endoscopic follow-up, with an emphasis on behavior and risk modification to avoid NSAIDs and tobacco, in addition to continuing oral proton pump inhibitor treatment—the latter of which has demonstrated a reduction in marginal ulcers after Roux-en-Y gastric bypass.²⁵ Some studies have shown a benefit with sucralfate therapy for patient symptoms and decreased acid production¹²; its use is variable but is in favor among the bariatric surgeons here in our practice.

INDICATIONS FOR SURGERY

Patients fall into categories from emergent to elective, that is, the bleeding, hypotensive patient to the patient who has failed medical therapy. The majority of patients who require thoracoscopic evaluation generally fall into the elective category as they belong to the minority that fails either short- or long-term medical therapy, are prohibitive risks toward an abdominal approach, and require thoracoscopic surgery. These patients have often exhausted maximal therapy, including twice-daily proton pump inhibitor treatment, sucralfate, and avoidance of NSAIDs and smoking. Patients with bleeding ulcers may be on vitamin K antagonists, antiplatelet agents, factor Xa inhibitors, or more novel anticoagulants, and though temporarily held, continue to bleed and require treatment given the long-term cardiovascular risk of withholding medical therapies. And despite close endoscopic surveillance and interventions including clipping, thermocoagulation, or injection with vasoconstrictive agents, the re-bleeding rates remain high.²⁴

SURGICAL OPTIONS

Several options exist for the refractory marginal ulcer and can be tailored given the patient's specific anatomy, clinical presentation, and overall tolerance to morbidity. In patients with a history of laparoscopic Roux-en-Y gastric bypass without gross perforation and peritonitis, repeat laparoscopic oversewing of the ulcer may be sufficient. Some have also recently described an omental patch repair for marginal ulcer perforation,²⁶ heralding similar perioperative morbidity, length of operative time, and hospitalization of the Graham patch repair. However, more morbid procedures, including revision of the anastomosis and reversal of the bypass, have been well-described in several studies²⁷ and

remain appropriate for certain candidates. Utilizing preventive measures, one group in the mid-1990s preemptively performed proximal vagotomy and posterior truncal vagotomy on their elective Roux-en-Y gastric bypass patients with no marginal ulcer complications at 18 months; however, longer-term data were not reported in this group.²⁸ Some groups have described revision of the gastrojejunostomy along with truncal vagotomy from an abdominal approach to help marginal ulcers heal and not recur.^{29,30}

TRANSTHORACIC VAGOTOMY

Background

These interventions can be generally characterized as “subdiaphragmatic” and together represent the majority of revisional surgery for marginal ulcers. Transthoracic vagotomy, popularized in the mid-1960s,³¹ was employed as a staged procedure for a patient who had undergone initial “damage-control” surgery for a hemorrhaging ulcer and subsequently needed definitive vagotomy after gastrotomy and ligation. The concern for limited or nonvisualized ulcer via transthoracic approach was addressed in the late 1970s as endoscopy was in its investigative phase to directly visualize and confirm the presence of marginal ulcers prior to definitive treatment.³² In the 1980s, the transthoracic approach was described again in the context of patients who had undergone a variety of transabdominal vagotomy and/or partial gastrectomies with recurrence who were shown to have inadequate vagotomy or regeneration of these transected nerves by measuring acid output.³³ The use for transthoracic vagotomy expanded in the 1990s, then employed for patients with refractory gastroesophageal reflux disease who had undergone acid-reducing procedures, including funduplications that now created distorted anatomy and made for a difficult transabdominal approach.³⁴

With the introduction of laparoscopy and its rapid utilization in the late 1980s and early 1990s, soon followed its video-assisted counterpart in thoracic surgery. The first published video-assisted thoracoscopic approach to the recurrent ulcer was in 1992 by a group in Birmingham, Alabama,³⁵ and took off to include not only patients with recurrent gastric ulcers, but also those with marginal ulcers after Roux-en-Y gastric bypass with low recurrence rates and decreased morbidity compared to anastomotic revisions.³⁶

Preoperative assessment

As noted earlier, many of these patients undergo significant medical workup, including repeated endoscopy to localize and treat the ulcer, and maximal medical therapy before consideration for video-assisted thoracoscopic surgery. Preoperative evaluation must include a detailed history and physical, including behavior and risk assessment, prior abdominal and thoracic interventions (including detailed operative notes on

prior attempts at vagotomy), and cardiopulmonary assessment. A preoperative type and screen is needed, in addition to preoperative chest x-ray and electrocardiogram. If the patient has a significant smoking history, pulmonary disease, or prior lung resection, pulmonary function tests may be indicated to evaluate for tolerance to single-lung ventilation.

Relevant anatomy

The distal esophagus is most accessible with the patient's left-side up, or right lateral decubitus position. Given the embryologic rotation of the foregut, the left vagus nerve generally runs anterior to the esophagus, and the right vagus nerve runs posterior. Following caudad, there lies a 2–3 cm intra-abdominal portion of the esophagus, followed by the angle of His. The thoracic aorta lies posterior to the esophagus, with several feeding lumbar and esophageal branches; the first main trunk in the abdomen is the celiac trunk, which also provides vascular supply to the distal esophagus.

Operative details

PREOPERATIVE PHASE AND POSITIONING

The patient is appropriately consented and is evaluated by both the Surgical and Anesthesia teams prior to entering the operating room. Epidural anesthesia is generally not indicated, as most of our patients are capable of managing pain with a pain-controlled anesthetic device postoperatively. An arterial line is often placed for closer hemodynamic monitoring during the case, though this is generally reserved for wedge resections and lobectomies. The patient receives preoperative unfractionated subcutaneous heparin for deep vein thrombosis prophylaxis and dose of first-generation cephalosporin antibiotic for surgical site infection prophylaxis prior to skin incision. Induction is performed with the patient in the supine position, with a double-lumen endotracheal tube placed and confirmed by the anesthesiologist. The tube is secured, and the patient is then placed in the right lateral decubitus position, with the right lower extremity extended and the left lower extremity slightly flexed. All bony prominences are appropriately padded to avoid postoperative neuralgia.

EQUIPMENT AND PORT PLACEMENT

Two high-definition monitors are placed on either side of the table toward the head of the patient, directly facing the surgeon and the assistant. After confirming that the lung is down on the operative side, the first port is placed in the ninth intercostal space at the posterior axillary line, and swept bluntly prior to insertion of instruments to avoid diaphragmatic injury. Two additional working ports are placed, one more anteriorly in the fifth or sixth intercostal space, and the second more posterior, parallel to the tip of the scapula. An additional port for retraction or suction may be utilized, usually placed inferior to the most posterior port ([Figure 68.1](#)).



Figure 68.1 Patient positioning and port placement: Scapula and axilla are marked (solid black line and *, respectively); left arm is extended anteriorly.

The surgery progresses from exposure of the esophagus circumferentially to identification and division of the vagus nerves. To gain exposure to the distal esophagus, the inferior pulmonary ligament is often divided with a monopolar device with the left lower lobe of the lung retracted anteriorly. The parietal pleura overlying the esophagus is opened with monopolar cautery ([Figure 68.2a](#)).

At this point, the anterior and lateral aspects of the esophagus are exposed, taking care to cauterize any small aortoesophageal vessels that are encountered. The anterior vagus is identified. Once the esophagus is circumferentially freed from the periesophageal nodal and other tissue, it is retracted leftward out of its mediastinal bed so that the posterior vagus may be identified. A Penrose catheter may be passed around the esophagus to facilitate retraction, or a thoracoscopic Harken clamp may be used, taking care not to traumatize the muscle layers ([Figure 68.2b](#)). The anterior and posterior vagus nerves are divided with monopolar, or by clipping them and dividing them with scissors, sending the excised nerve to pathology ([Figure 68.2c and d](#)). The esophagus should be assessed circumferentially to be sure that no rami have been left undivided.

A chest drain is left in place, and the lung is re-expanded under direct visualization. The chest drain is secured, and the patient is extubated. The postoperative course includes pain control, chest drain removal, and usually continuation of the patient's pharmacologic acid-reducing therapy, which is discontinued at the discretion of the patient's gastroenterologist.

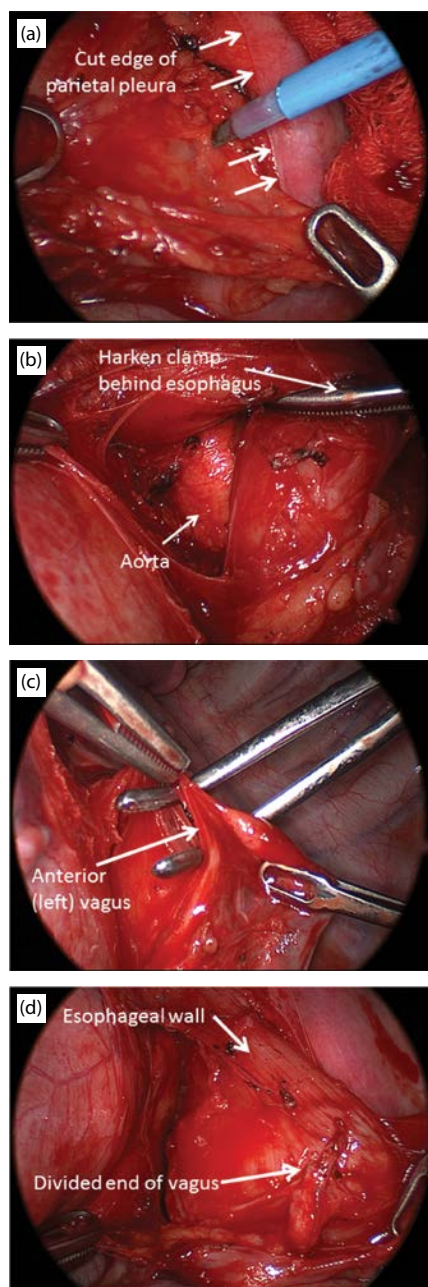


Figure 68.2 (a) Dissection of esophagus: Mediastinal pleura has been incised, and periesophageal fat is being divided with monopolar. (b) Circumferential dissection of esophagus: Harken clamp has been placed behind esophagus in order to expose posterior vagus. (c) Anterior vagus exposure: Clamp dissecting vagus nerve from esophageal wall. (d) Divided anterior vagus: Cut edge of nerve.

SUMMARY

Peptic ulcer disease historically has challenged both the medical and surgical fields with a significant evolution in therapies since the early twentieth century. Despite these advances, recurrent peptic and marginal ulcers continue to carry high morbidity and mortality, particularly with an aging

population. With the advent of endoscopy, laparoscopy, and thoracoscopy, the treatment of marginal ulcers has become a more active presence for the primary physician, gastroenterologist, and surgeon. Patients often exhaust the treatment algorithm prior to definitive revisional surgery to the gastrojejunal anastomosis, which may be prohibitive given multiple prior abdominal surgeries. Thoracoscopy therefore plays a significant role in the patient who has had multiple prior abdominal surgeries or those who may otherwise not be low-risk candidates given prior attempts at vagotomy and unclear or distorted anatomy. Described as early as the 1960s, transthoracic vagotomy, and now a mostly thoracoscopic-driven procedure, is a less morbid, definitive surgical option for those with refractory marginal ulcer disease with good results and decreased reoperation rate. Success rates of over 80% with thoracoscopic truncal vagotomy alone for the treatment of recalcitrant marginal ulcers have been reported.

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Intragastric balloon

ALFREDO GENCO AND ILARIA ERNESTI

INTRODUCTION

The intragastric balloon (IGB) owes its pathophysiological concept to the original observation that patients affected by an intragastric agglomeration of partially digested hairs and vegetable fibers, otherwise known as bezoar, could complain of postprandial fullness, nausea, and vomiting. This led to the idea of designing a device that would imitate an intragastric bezoar by partially filling the stomach.¹

The history of IGB began in 1985 with the first intragastric balloon: Garren-Edwards Gastric Bubble (GEB, American Edwards Company, Santa Ana, California). It was approved by the U.S. Food and Drug Administration (FDA) for temporary use as a weight loss device.

Adverse events related to this device reported in the medical literature included significant complications, such as gastric ulceration and erosion and intestinal obstruction.

Moreover, several randomized trials showed no added benefits compared to sham treatment when combined with standard weight loss programs.²

For these reasons, in 1992 GEB was voluntarily removed from the market.

In 1987, an international and multidisciplinary conference in Tarpon Springs, Florida, defined the features of the ideal intragastric balloon: effective at promoting weight loss, filled with liquid (not air), has a soft surface with low ulcerogenic and obstructive potential, has a spherical shape, and contains a radiopaque marker for easy visualization once in the stomach.³

According to these recommendations, the BioEnterics Intragastric Balloon (BIB, Allergan Inc., Irvine, California) system was made up of a soft, transparent, silicone balloon connected by means of a radiopaque valve, to a “placement” catheter with a 6.5 mm external diameter, also made of soft silicone. Three fundamental factors distinguished the BIB from the bubbles of the 1980s: the liquid content that made it definitely more effective, the “self-sealing” radiopaque

valve, the spherical form, and the silicone structure that rendered the complication of ulcers extremely rare (as according to previous indications).

In 2013 Apollo Endosurgery Inc. acquired the BIB technology that was renamed Orbera.

In the last decades, several IGBs were subsequently developed, showing a high safety and efficacy profile.⁴

To date, IGBs can be classified as shown in [Table 69.1](#).

The information in this chapter mainly refers to the intragastric balloon, with FDA approval, available on the U.S. market: the Orbera Intragastric Balloon System and the ReShape Duo Intragastric Balloon.

ORBERA INTRAGASTRIC BALLOON SYSTEM

The Orbera (formerly Bioenterics) Intragastric Balloon System (Apollo Endosurgery, Austin, Texas) is placed and removed endoscopically and filled with 500–700 mL saline. Due to its resistance to gastric acid, the Orbera could be indicated for up to 6 months of treatment.⁵

This balloon is the most used and known, and received FDA approval in August 2015. For these reasons, most of the following information refers to this device⁶ ([Figure 69.1](#)).

Mechanism of action

The mechanism of action is based on these characteristics:

- The weight of the balloon (gas or liquid filled) stimulates the baroreceptors/stretch gastric receptors activating the brain-gut axis and stimulates the satiety center, placing it at the hypothalamic level.
- The space-occupying device induces a reduction of gastric volume (about 5–700 cc of space), and, hence, a reduction of food intake.

Table 69.1 Classification of intragastric balloon

Intragastric balloons	Endoscopically	Swallowable	Liquid filled	Gas filled	Duration (months)	FDA approved	Adjustable
Orbera	x		x		6	x	
ReShape	x		x		6	x	
Heliosphere	x		x		6		
Silimed	x		x		6		
Spatz3 adjustable	x		x		12		x
Endalis	x		x	x	6		
EasyLife	x		x	x	12		x
Medsil	x		x		6		
Obalon		x		x	3–6		
Elipse		x	x		4		

**Figure 69.1** Orbera Intragastric Balloon System.

- Delayed gastric emptying, the most important mechanism, may be due to stretching of the gastric musculature or could be related to changes in circulating levels of leptin and ghrelin.²

Indications and contraindications for IGB treatment

The Orbera balloons are indicated in an overweight or obese patient with a history of numerous failures of dietary treatment.

Present indications suggest IGB treatment in the following:

- Patients with body mass index (BMI) > 27 kg/m² with obese-related comorbidities (European Union indication)/patients with BMI 30–40 kg/m² (U.S. indication)
- Patients with BMI 35–49.9 kg/m² or super-obese patients (BMI > 50 kg/m²), as a bridge to surgery (bariatric, orthopedic, cardiac, etc.) to reduce the operative risk and the incidence of postoperative complications; patient refusing bariatric surgical procedure in order to achieve a satisfactory weight loss or, at least, weight stability

- Obese patients preventing or delaying the natural history of weight gain

At the moment, there are no specific recommendations regarding age limits. The device could, therefore, also be used for children and for elderly persons.

Placement of Orbera or other IGBs is contraindicated, at present, in patients with the following:

- Large hiatal hernia (5 cm)
- Esophagitis > B grade (Los Angeles classification)
- Duodenal/gastric ulcer
- Potential bleeding conditions of the upper gastrointestinal tract
- Outcomes of prior, major surgical operations on the gastrointestinal tract and/or certified adhesion syndrome
- Neoplasia
- Conditions requiring chronic treatment with anti-inflammatory drugs or anticoagulants
- Major psychiatric disorders or who are noncollaborative
- Alcohol or drug dependency
- Certified pregnancy
- Inflammatory bowel diseases (e.g., Crohn disease, etc.)⁷

Preoperative workup

All patients should perform the following tests before IGB placement:

- Complete blood analysis
- Electrocardiogram and cardiologic video
- Diagnostic esophagogastroduodenoscopy with *Helicobacter pylori* (HP) test to rule out the presence of contraindications to balloon placement
- Endocrinological and dietetic assessment examinations to exclude endocrine-based obesity
- Psychiatric clinical evaluation to exclude psychiatric diseases and eating disorders (e.g., “sweet eating,” “binge eating disorders,” etc.)
- Lung function test, spirometry, and sleep study, in obese patients with a BMI > 50 kg/m² or in high-risk obese patients (regardless of BMI)

Placement and removal technique

Orbera IGB placement and removal can be performed in conscious sedation with diazepam or midazolam, in unconscious sedation with propofol, or with orotracheal intubation. Before placement, a diagnostic esophagogastroduodenoscopy is performed. Then the balloon is positioned with the valve under the cardia and is filled with 500–700 mL of saline solution under endoscopic vision. Moreover, methylene blue (10 mL) is used in European clinical experience in order to early identify the balloon rupture or valve leaks. This dye is contraindicated in patients with glucose-6-phosphate-dehydrogenase (G-6-PDH) deficit, due to the risk to hemolysis crisis in case of its release. Finally, the connection catheter is removed, and the valve is checked for possible leaks. The procedure lasts on average 15 minutes.

The Orbera removal is carried out after 6 months. Recently, is available the new Orbera 365 that is the same balloon but can sit in the stomach for 12 months. Clinical studies about its efficacy are in progress.

Due to the delayed gastric emptying achieved with the balloon, the removal procedure should be preceded by a 24 hours semiliquid diet, in order to avoid “ab ingestis,” chiefly when the procedure is performed in unconscious sedation.

Through an esophagogastroduodenoscopy, the Orbera is identified and is removed with a dedicated “grasper” after the completed deflation. Stomach observation is necessary to exclude possible mucosal lesions.⁸

Postplacement management

PHARMACOLOGICAL TREATMENT OF SYMPTOMS

Pharmacological treatment of symptoms should be considered as a part of a comprehensive strategy of IGB management. During the first 2–3 days, the device could induce symptoms such as nausea, regurgitation or vomiting, and cramp-like epigastric pains. These tend to last only for a short period (2 or 3 days) after balloon insertion and are usually self-limiting.

In order to reduce or prevent these distressing adverse effects, all patients must receive an adequate medication based on fluids hydration, proton pump inhibitors, antispasmodic drugs, and antiemetic drugs.

A prospective controlled study conducted on 54 patients receiving IGB treatment showed that the use of midazolam combined with ondansetron provides significant reduction of the postoperative nausea and vomiting compared to ondansetron alone.⁹ In our clinical experience, Aprepitant (125 mg orally the first days, 2 hours before the procedure, and 80 mg the first and second day after placement) induces good control of vomiting episodes. Daily intake of full-dose proton pump inhibitors should be prolonged until IGB removal.

POSTPLACEMENT DIET

The postoperative IGB diet should be divided into three steps: For the first day, patients should take fluids only; from the second and up to the sixth to seventh days, a semiliquid

diet (yogurt, mashed potatoes, and puréed vegetables), and generally, at the beginning of the second week return to a normal textured diet, though with caution. The dietetic program, elaborated by nutritionists, is based on a daily intake of about 1000–1200 Kcal (including at least 1 g protein/kg ideal weight), consumed over three main meals and two small snacks. This program has been maintained until removal of the IGB and, in case of nausea, regurgitation or vomiting is indicated to return at semiliquid diet for some days. Our experience shows that the daily consumption of a high volume of vegetables is inadvisable due to their poor digestion. They clog up the gastric cavity and cause regurgitation or vomiting. It is therefore advisable to prescribe vegetables in soup form.

Although indications have not yet been fully standardized, this nutritional schedule could reduce the symptoms related to IGB placement.

Patient Follow-Up

Follow-up and continued supervision are necessary to prevent possible adverse events.

All patients are contacted by phone every day for the first week after IGB placement. Undergoing a nutritional and clinical evaluation on the eighth day and every 2 weeks until the removal, they receive the nutritional program to follow until IGB removal. Before discharge, the patient is made aware of the importance of adequate hydration (water at least 1.5 L/day to sip slowly) and of ongoing urine checks, in order to report quickly the premature rupture of the IGB or a possible valve leak.

In case of complication (e.g., blue urine or recurrent vomiting), an immediate clinical evaluation is essential, and an urgent x-ray or esophagogastroduodenoscopy may be indicated in order to exclude the risk of migration of the deflated balloon and bowel obstruction. Moreover, serious side effects with the Orbera IGB are rare, with an incidence of obstruction and gastric perforation of 0.8% and 0.1%, respectively. The confirmation of decubital ulcers or gastrectasia indicates the need to remove the IGB.¹⁰

Orbera Outcomes

WEIGHT LOSS

To date, the largest trial on Orbera was published in 2005 by the Italian Lap-Band and BIB group (GILB). In this clinical trial, accounting for 2,515 patients with a mean initial BMI of 44.4 kg/m² and a mean excess weight of 59.5 kg, after 6 months of IGB treatment the mean BMI loss and the mean percentage of excess weight loss (%EWL) was, respectively, 4.9 kg/m² and 33.9%. Moreover, during this period, the treatment with Orbera was demonstrated to be effective in resolving or improving obesity-related comorbidities in 44.3% and 44.8%, respectively, while no changes were reported in 10.9% of patients.¹¹

In a multicenter Brazilian study of the IGB, 323 patients (mean BMI 38.2 kg/m²) who completed 6 months of follow-up after Orbera showed highly significant reductions in BMI (−5.3 kg/m²) and a %EWL of 48.3%.¹²

The American Society for Gastrointestinal Endoscopy (ASGE) Technology Committee performed systematic reviews to evaluate the Orbera clinical outcome in terms of weight loss. Based on a meta-analysis of 17 studies including 1,683 patients, the %EWL at 12 months was 25%. Three Randomized Clinical Trials (RCTs) compared %EWL in patients who received the Orbera IGB, showing a mean difference in %EWL in patients who received the Orbera IGB over controls of 26.9% ($p = 0.001$).

Based on a recent review, seven studies (409 patients) reported the weight loss kinetics during IGB placement. Mean weight losses after 3 and 6 months of Orbera treatment are 12.9 ± 0.8 and 16.0 ± 0.6 , respectively. These data indicate that the most weight loss occurs in the first 3 months, suggesting that the mechanism of action is more active at the beginning of treatment.¹⁰

Moreover, Orbera is a repeatable treatment, after an IGB-free period. The effectiveness of a second Orbera balloon placement was investigated in clinical trials. Scientific literature reported that at the end of the second IGB treatment, after a 1-month IGB-free period, patients continued to lose weight, and as compared to patients treated with diet alone, there was a significant reduction in weight loss parameters.^{13,14}

Although the second IGB therapy results in a continuous weight loss, its magnitude was smaller than that of the initial therapy.

METABOLIC OUTCOMES

The metabolic effects of Orbera IGB placement were examined in several studies.

Data from the Italian Lap-Band and BIB group (GILB) showed that diabetic patients undergoing IGB treatment achieved a resolution or improvement in 32.8% and 54.8%, respectively.

A prospective study of Forlano et al. analyzed the metabolic effect of the device on ameliorating some components of the metabolic syndrome in 130 obese patients. The results showed a significant improvement of blood glucose, insulin, triglycerides, and alanine aminotransferase and of the value of the homeostatic model assessment index.¹⁵ In a prospective, controlled parallel arm, 66 obese adults were randomized to receive either the IGB for 6 months in addition to a behavioral modification program of diet and exercise, or the behavioral modification program alone. The authors reported statistically significant and clinically relevant improvements in weight loss and in health outcomes (reduction of waist circumference, improvement in quality of life, and an approximately half remission of metabolic syndrome) in IGB group versus behavioral modification alone group.¹⁶

Interestingly, a longitudinal and interventional study on 40 obese/overweight patients found a statistically significant improvement for the metabolic syndrome parameters and pulmonary function variables, leading to a reduction of the restrictive-ventilatory defect.¹⁷

Complications

The rates of adverse events after Orbera IGB implantation were pooled from a recent review of 68 studies. The early removal rate for the Orbera IGB was approximately 7%. The most common side effects associated with device placement are nausea, vomiting, and abdominal pain, occurring in 33.7% of subjects. These symptoms generally resolved within 7 days of device placement. Serious side effects are rare, with an incidence of bowel migration of 1.4% and gastric perforation of 0.1%. Four deaths were associated with Orbera IGB treatment and are related to gastric perforation or an aspiration event.¹⁰

RESHAPE DUO INTEGRATED DUAL BALLOON SYSTEM

ReShape Duo (Medical Inc., San Clemente, California) is made as double spheres filled with a total of 900 mL saline, to prevent migration if one sphere deflates. It is endoscopically placed in the stomach and retrieved following 6 months of treatment. The insertion and retrieval procedures average 8 minutes and 14 minutes in duration, respectively.

A prospective, randomized, sham-controlled trial of ReShape Duo included 264 participants (ages between 21 and 60 years) with a baseline BMI ≥ 30 and ≤ 40 kg/m². The patients were randomized to endoscopic Duo treatment plus diet and exercise (DUO patients) or a diet and exercise regime (DIET patients). After 24 weeks of treatment, DUO patients had the device retrieved. The primary endpoint of the study showed that the DUO patients had a $25.1 \pm 1.6\%$ EWL versus $11.3 \pm 1.9\%$ EWL of the DIET patients ($p = 0.004$). Comorbid conditions, such as glucose and lipid profile, blood pressure, and waist and hip circumference, showed significant improvement through the completion of 48 weeks of follow-up. During the study there were no deaths, no intestinal obstructions, and no gastric perforations. In 6% of DUO patients, device deflation was observed, without device migration. Gastric ulceration was found in 35% of treated patients. Although this rate significantly decreased after a minor modification to the device's distal tip, the incidence of gastric ulceration remains consistent (Figure 69.2).¹⁸

LAST-GENERATION INTRAGASTRIC BALLOONS

A class of new balloons just arrived on the market. This class includes a procedure-less balloon; this means that it does not require endoscopy or sedation for either placement or removal. The Elipse IGB (Allurion Company, Boston, Massachusetts) is a polyurethane balloon that a patient can swallow easily with a glass of water. This balloon is enclosed in a dissolvable vegetarian capsule attached at a thin catheter (about 75 cm long) used for filling it. Once the capsule is swallowed, its position is confirmed using an abdominal x-ray. If a patient has difficulty swallowing the capsule, a stylet can be fed through the



Figure 69.2 Contrast medium abdominal-RX of Intra-gastric Re-Shape Balloon.

catheter to stiffen it. This balloon has a small radiopaque ring inside, which visualizes before filling it. When it arrives in the stomach, Elipse is filled with 550 cc of solution, and the catheter is removed by pulling it back. After 4 months the valve dissolves, the liquid is lost, and the empty balloon is evacuated spontaneously by the natural way (**Figure 69.3**).

In our study,¹⁹ 38 consecutive patients were enrolled (female/male 28/10, mean age 46.4 ± 10.6 years, mean weight 109.7 ± 21.9 kg, and mean BMI 38.6 ± 6.7 kg/m²). All patients swallowed the capsule, and after 4 months the balloon spontaneously emptied and was excreted through the digestive tract without upper endoscopy. No serious adverse events were observed during the treatment, 37 balloons were safely excreted in the stool, and 1 balloon was endoscopically removed due to a binge eating disorder not previously diagnosed. In particular, there were not gastric perforations, symptoms of ulceration, intestinal obstructions, or gastrointestinal hemorrhage. The most common adverse event after deployment was nausea.

After 16 weeks, the mean weight loss was 12.7 kg, mean percent excess weight loss was 26%, and mean BMI reduction was 4.2 kg/m². Total body weight loss was 11.6%. We also found a significant reduction in major comorbidities related to metabolic syndrome: blood pressure ($p < 0.02$), waist circumference ($p < 0.002$), triglycerides ($p < 0.0001$),



Figure 69.3 Elipse balloon system.

blood glucose ($p < 0.001$), and homeostatic model assessment–insulin resistance index ($p < 0.001$).

A multicenter, prospective analysis of 135 patients who underwent Elipse balloon insertion has recently been published.²⁰ At the 4-month mark, the mean weight of the patients showed a drop of 13 kg, and the mean BMI showed a drop of 4.9 units. The mean percent total weight loss was 15.1%. All patients reported nausea in the first day of insertion; however, 69.6% reported complete resolution by the third day. Two patients (1.5%) vomited the balloon early, 3 patients (2.2%) had to have the balloon removed early due to intolerance, 3 patients (2.2%) experienced early deflation, 18 (13.3%) patients reported episodes of diarrhea around the time of deflation, and 29 (21.5%) patients experienced colicky abdominal pain in the week of balloon deflation. One patient experienced small bowel obstruction, after which the balloon was removed via laparoscopic enterotomy.

These results demonstrate that the Elipse balloon can be safely and easily swallowed, filled, and passed through the gastrointestinal tract. In addition, this device is effective in inducing weight loss and seems to be able to reduce the obesity-related metabolic diseases including metabolic syndrome.

Obalon balloon

The novel Obalon system was approved by the FDA in September 2016. This balloon is designed to be swallowed in gelatin capsules and inflated with 250 cc of gas without the need for endoscopy or sedatives. Over the next 3 months of treatment, according to patient's satiety, two additional balloons are swallowed and inflated. At the end of the 6-month treatment period, all three balloons are removed via an outpatient endoscopy under conscious sedation.

In the U.S. clinical trial, 387 patients were randomized in a double-blind, sham-controlled study. Approximately 65% of patients who received the Obalon balloon system experienced clinically meaningful weight loss of at least 5% of

their total body weight, which is twice as many people than in the sham-control group.²¹

The balloon seems to be well tolerated, with lower incidence of accommodative symptoms compared to those observed with other fluid-filled balloons.²²

CONCLUSION

IGB treatment may represent a good option in the management of comorbidities of obese patients refusing surgery or as a bridge to any kind of surgery to reduce anesthesiological and surgical risks.

Furthermore, IGB is not able to cure obesity. But, this treatment may play a very important role to prevent morbid obesity. For this reason, it is strongly recommended for early treatment of patients with lower BMI or overweight.

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Minimally invasive treatment of hepatobiliary disease



Joseph Beuys, *Zeige deine Wunde* (Show Your Wound), 1974–75. Blackboards, hospital tables, farm tools, zinc-coated boxes filled with grease, framed newspapers, glass jars; dimensions variable. Städtische Galerie im Lenbachhaus, Munich.
(Photo courtesy Lenbachhaus. © 2018 Artists Rights Society [ARS], New York/VG Bild-Kunst, Bonn.)

In the spring of 1944, at the height of the Second World War, Joseph Beuys (then a rear gunner in the German Luftwaffe) was involved in a plane crash in the Crimea. Beuys survived the incident, but his pilot was instantly killed. Returning from the front, he decided to become an artist instead of returning to his plan to begin medical training. Although he would never discuss his wartime trauma, the crash became

an important touchstone in his career. He later recounted a fictionalized story of his salvation by a group of nomadic tribespeople, who wrapped him in fat and felt, two key materials in his work, which purportedly helped heal his wounds. This myth helped him to conceptualize his feelings of guilt and anguish (as well as those of all Germans) and redirect them toward healing German society after the war.

Beuys's installations physically embody this goal through elements that represent transformation and energy flows, such as hardened margarine, metal plates, and pieces of felt. These materials often took part in his live performances, during which he appeared in the role of a shaman. Medical paraphernalia, such as discarded pill bottles, bandages, figures of the red cross, and even a decommissioned ambulance, were also common features in his work. For him, these were much more than just abject articles; they were metaphors for treating social and political problems, such as nuclear armament, environmental destruction, and over-specialized labor.

The materials in *Show Your Wound*—hospital gurneys, farming tools wrapped in cloth, boxes filled with grease, and blackboards—were initially installed by the artist in a pedestrian underpass in Munich in 1974–75. When combined with the sound of traffic from above, the effect was that of a ghoulish, inhospitable environment. Beuys often spoke of the “wound,” in terms of his own personal injuries in the war, subsequent mental breakdown, and later heart problems, as well as in reference to Germany's past and its then-present division between capitalist West Germany and communist East Germany. This work may thus reference his own deteriorating health, while suggesting the potential for healing social divides.

Laparoscopic cholecystectomy and intraoperative biliary imaging

ROBERT D. FANELLI, THOMAS J. VANDERMEER, AND BRANDON D. ANDREW

INTRODUCTION

Thirty years ago, the widespread introduction of laparoscopic cholecystectomy (LC), first performed by Mouret in 1988 in Lyon, France, revolutionized our approach to gallbladder disease and forever changed the practice of general surgery.¹ Although LC arguably has become one of the most commonly performed abdominal operations worldwide, there remains much interest in defining and refining its optimal techniques. In just the first 75 days of 2015 alone, there were more than 115 articles published in the English-language medical literature, debating the timing of operative intervention, the safest dissection techniques, appropriate management of complications, and the routine use of intraoperative cholangiography (IOC), among other things.^{2–4} This chapter approaches LC with an emphasis on patient safety and will make recommendations for patient selection, operative timing and techniques, and the use of intraoperative biliary imaging that we believe represent current best practices in biliary surgery.

INDICATIONS FOR SURGERY

Stone disease

The majority of LC performed is intended to treat symptoms or complications related to biliary stone disease. These include biliary colic, acute and chronic cholecystitis, choledocholithiasis, and biliary pancreatitis, among others.⁵ It is estimated that as many as 10% of the population of the United States has gallstones and that roughly 20% of these individuals are symptomatic at the time their gallstones are discovered. Although nearly 80% of patients with gallstones

initially are asymptomatic, symptoms develop in 4%–10% of asymptomatic individuals per year, necessitating treatment in a majority of them.⁶

Clinically apparent gallstones most commonly present with symptoms related to recurring episodes of biliary colic; postprandial crescendo-decrescendo right upper quadrant, and often epigastric, pain with a duration of minutes to hours that radiates around the right thorax, to the tip of the right scapula, or straight through to the midscapular region. Most episodes follow fatty meals, but some occur spontaneously, often around midnight, and other symptoms may include bloating, eructation, flatulence, and dyspepsia or atypical abdominal pain; some patients describe transient abdominal soreness after resolution of their acute symptoms.⁷

Most patients with biliary colic are evaluated in the outpatient setting, undergoing transabdominal right upper quadrant ultrasound, and often liver chemistries and other laboratory studies, after discussing suggestive symptoms with their primary care or specialty provider. Some patients undergo abdominal or abdominopelvic computed tomography (CT) scanning for evaluation of right upper quadrant abdominal pain, especially those seen in the emergency department setting.⁸ Ultrasound generally is regarded as more sensitive for small gallstones as compared with CT, although some studies have suggested that they are equally sensitive in the diagnosis of acute cholecystitis.^{9,10} Endoscopic ultrasound (EUS) sometimes is used in challenging diagnostic scenarios, favored for its superior sensitivity compared with transabdominal ultrasound, CT, and magnetic resonance imaging (MRI).¹¹

About 30% of patients with symptomatic cholelithiasis present initially with a complication of their gallstones;

acute cholecystitis, choledocholithiasis, biliary pancreatitis, sepsis, or gallstone ileus, among others.^{12,13} Although this group of patients most typically requires urgent or emergent treatment for their gallstone-related illnesses, a majority of patients with symptomatic gallstones will be treated electively, most with outpatient or short-stay LC. Patients with clinically silent gallstones typically are not treated with LC except in special circumstances, such as patients with sickle cell disease and those with certain other medical conditions, where preemptive LC may be advised.¹⁴

NONSTONE DISEASE

There is a subset of patients with right upper quadrant abdominal pain and other typical and atypical biliary symptoms who, on ultrasound, are found not to have cholecystolithiasis. During the era when open cholecystectomy was the only available treatment, patients with these syndromes less commonly underwent elective cholecystectomy. However, since the advent of LC, there has been much interest in characterizing these nonstone syndromes to determine treatment best practices.^{15–18} The entities most often considered in evaluating patients without gallstones who manifest symptoms suggestive of biliary pathology are acalculous cholecystitis, biliary dyskinesia, and what broadly is referred to as functional gastrointestinal disease.

ACUTE ACALCULOUS CHOLECYSTITIS

Acalculous cholecystitis is a serious inflammatory disease of the gallbladder that accounts for as many as 10% of cases of acute cholecystitis.¹⁹ Diabetic patients, those with heart failure, renal disease, sepsis, malignancy, or hospitalized victims of traumatic injury along with many other compromised patients are at risk for bile stasis and subsequent gallbladder wall ischemia, leading to focal gallbladder wall necrosis, advanced inflammatory response, and in severe cases, perforation.²⁰ Secondary infection with *Escherichia coli*, *Enterococcus faecalis*, *Klebsiella*, *Pseudomonas*, *Proteus* species, or *Bacteroides* species is common, and the diagnosis should be suspected in severely ill patients who develop abdominal pain, sepsis, abnormal liver function tests, and leukocytosis; some patients will have a palpable inflammatory mass in the right upper quadrant and 20% of patients with acute acalculous cholecystitis present with jaundice.²¹ Gallbladder wall thickening, striations, emphysematous changes, pericholecystic fluid, and gallbladder distension seen on imaging studies support the diagnosis; cholecystectomy is considered definitive therapy and is preferred over cholecystostomy tube placement or endoscopic biliary drainage.²⁰ Advances in critical care management and the diagnosis and treatment of sepsis have been associated with improved outcomes for patients with acute acalculous cholecystitis.

FUNCTIONAL GALLBLADDER DISEASE

Functional gallbladder disease (FGBD) is a catchment term that includes disorders previously known as biliary dyskinesia, gallbladder dyskinesia, chronic acalculous cholecystitis, biliary spasm, and cystic duct syndrome. It is defined by the presence of biliary-type pain in the absence of gallstones, in patients where other important etiologies of pain have been ruled out with sufficient certainty.²² Patients with FGBD have normal liver chemistries and pancreatic enzymes. Gallbladder ultrasound examination is negative for gallstones, sludge, and cholesterosis and cholesterol polyposis. Many patients with this constellation of symptoms and these clinical and laboratory findings undergo esophagogastroduodenoscopy (EGD), which often is negative for competing diagnoses. The Rome III criteria, published in 2006, provide a useful set of guidelines for the diagnosis and management of patients with functional gastrointestinal disorders (FGIDs), chief among them, biliary dyskinesia.^{23–26}

Patients are said to fulfill Rome III criteria for FGBD when their pain (1) is located in the epigastrium and/or right upper quadrant; (2) is recurrent but occurs at variable, nondaily, intervals; (3) lasts at least 30 minutes when it occurs; (4) builds progressively to a steady level; (5) is so severe as to interrupt daily activities or result in emergency department evaluation; and (6) is not relieved by antacids, physical activity and changes in position, or bowel movement. The prevalence of FGBD in patients with biliary-type pain, normal EGD, normal labs, and gallbladder ultrasound negative for stones, sludge, and cholesterol polyps is 8% in men and 21% in women.²³

Determining whether patients with FGBD should be considered for LC can be challenging, and numerous evaluations usually are necessary to rule out competing diagnoses, including a consideration of functional dyspepsia. Useful among evaluations is cholecystokinin (CCK) cholescintigraphy. This test is performed following an overnight fast by first administering 99mTc-diisopropyl-iminodiacetic acid (DISIDA) or 99mTc-hepatic iminodiacetic acid (HIDA), given as an intravenous bolus. As with ordinary DISIDA or HIDA scanning, the radiolabeled Technetium-based tracer will be concentrated within the gallbladder provided that the cystic duct remains patent. Baseline right upper quadrant radioactivity is measured, and when gallbladder radioactivity is maximal and hepatic radioactivity is minimal, typically 40–75 minutes after administration of the Technetium agent, CCK is administered. CCK is administered best as an infusion, using Sincalide 0.02 mcg/kg given over 30 minutes.²⁷ The practice of more rapid or substantially slower intravenous CCK administration, either as an intravenous bolus or infusion, cannot be recommended as the former is associated with patient cramping and intolerance and both are associated with variable results that invalidate comparison to established norms.²⁷ Thirty minutes after CCK infusion, the radioactivity in the gallbladder is once again measured, and the

gallbladder ejection fraction (GBEF) is calculated using the formula: $GBEF = (\text{baseline activity} - \text{activity 30 minutes after CCK infusion}) / \text{baseline activity}$.²⁷ A GBEF less than 40% is abnormal, although this varies across institutions; our unit considers a GBEF less than 33% abnormal. Fatty meal cholescintigraphy has been substituted for CCK cholescintigraphy during Sincalide shortages, or by preference at some institutions, with variable results.^{28–30} A standardized approach to stimulated cholescintigraphy is recommended.

Patients with FGBD should be considered for LC if they have an abnormal GBEF as determined by properly performed CCK cholescintigraphy, are unlikely to have a false-positive study related to diabetes mellitus, celiac sprue, cirrhosis, or the chronic use of calcium channel blockers, progesterone, opiates, octreotide, and benzodiazepines, and successfully have had competing diagnoses ruled out. In this setting, the likelihood of complete or significant relief of symptoms is high compared with nonoperative management. In patients with atypical symptoms, normal GBEF, or confounding conditions, the likelihood of significant relief of symptoms is markedly diminished, and the role for LC should be considered carefully.^{22,31–33} In our patients with typical biliary pain who have a normal GBEF but in whom competing diagnoses sufficiently have been ruled out, LC still may be considered if their biliary pain was elicited by Sincalide infusion during properly performed CCK cholescintigraphy and empiric treatments like acid suppression and a bowel regimen have failed to provide relief.

PATIENT EVALUATION AND PREPARATION

The preoperative evaluation of patients with symptoms and signs of biliary tract disease is aimed at confirming the diagnosis, excluding competing diagnoses, evaluating for concomitant biliopancreatic diseases like common bile duct (CBD) stones and biliary pancreatitis, and evaluating non-biliary health factors important to the proposed operation. As previously discussed, patients with biliary colic, acute and chronic cholecystitis, or functional gallbladder disease (FGBD) typically will be evaluated using one or several biliary imaging techniques and standard laboratory studies. Patients with typical calculous disease presenting with biliary colic or acute cholecystitis will next be assessed to determine the likelihood of CBD stones. Hospitalized patients with acalculous cholecystitis, secondary infection, and possible sepsis will be assessed to determine the likelihood of CBD pathology as well, and to include or exclude a diagnosis of cholangitis as treatment planning progresses, so that all causes of sepsis may be addressed. In the patient with FGBD, preoperative evaluations are aimed at accurately determining the GBEF and excluding competing diagnoses. In all patients, an assessment aimed at determining their fitness for surgery is an important component of the preoperative evaluation.

COMMON BILE DUCT STONES

CBD stones are found in 5%–15% of patients undergoing cholecystectomy, but the risk increases with age; 30%–60% of patients over age 70 who undergo LC will have CBD stones.^{34,35} CBD stones can be managed successfully preoperatively, intraoperatively, or postoperatively, but most surgeons would agree that making the diagnosis of CBD stones preoperatively allows the most efficient approach to their management to be planned regardless of the method utilized to address them. *Moderate* risk predictors for CBD stones include the following: (1) abnormal liver chemistries other than bilirubin; (2) age over 55 years; and (3) biliary pancreatitis on initial presentation. *Strong* risk predictors for CBD stones include the following: (1) bilirubin greater than 1.8 mg/dL but less than 4.0 mg/dL and (2) CBD dilation greater than 8 mm on abdominal ultrasound. *Very strong* risk predictors for CBD stones include (1) bilirubin greater than 4.0 mg/dL; (2) CBD stones seen on imaging studies; and (3) cholangitis on initial presentation.^{36–40} As the number and strength of risk predictors increases, so does the likelihood that CBD stones will be present (**Table 70.1**).

Complete discussion of the management of CBD stones is beyond the scope of this chapter. We advocate liberal use of IOC and intraoperative ultrasound in all LC, and in our practice we manage occult CBD stones identified during LC with laparoscopic endobiliary stent placement (Fanelli Endobiliary Stent Kit, Cook Surgical, Inc., Bloomington, Indiana) followed by postoperative endoscopic retrograde cholangiopancreatography (ERCP), or with laparoscopic common bile duct exploration^{41–43} (**Figure 70.1**). Our patients at intermediate and high risk for CBD stones, like those with biliary pancreatitis, undergo EUS followed by

Table 70.1 Predicting CBD stones in patients with cholelithiasis

Moderate predictors for CBD stones	
• Liver function test other than total bilirubin abnormal • Age greater than 55 years • Gallstone pancreatitis	
Strong predictors for CBD stones	
• Bilirubin >1.8 mg/dL but <4.0 mg/dL • Dilated CBD >8 mm on ultrasound	
Very strong predictors for CBD stones	
• Bilirubin >4 mg/dL • CBD stone visualized on ultrasound • Cholangitis	
Predictors	Risk of CBD stones
None	Low
One, two, or three moderate	Intermediate
One strong with/without moderate	Intermediate
Two strong	High
One or more very strong	High

Source: Adapted from Committee ASoP, Maple JT. *Gastrointest Endosc* 2010;71(1):2.⁴⁰

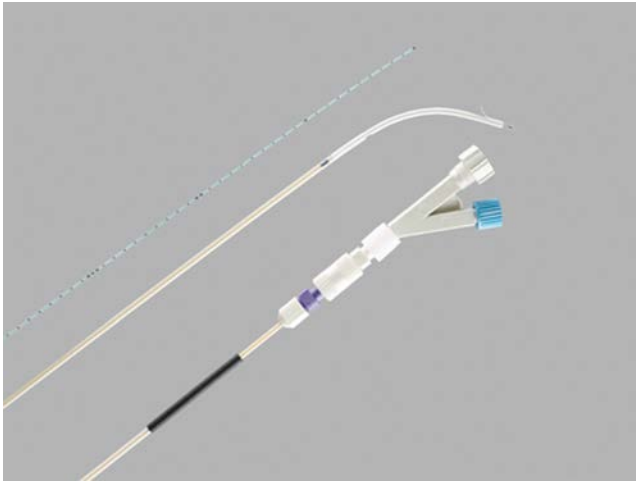


Figure 70.1 Fanelli laparoscopic endobiliary stent kit for management of occult choledocholithiasis when postoperative ERCP is the preferred treatment strategy. (Courtesy of Cook Surgical, Inc., Bloomington, Indiana.)

same-setting ERCP when CBD stones are identified. Very high risk patients who have had CBD stones demonstrated on biliary imaging studies are treated with preoperative ERCP or planned LC with laparoscopic common bile duct exploration, depending on the number and size of CBD stones. These management decisions should be made based on surgeon experience and available resources; the goal is safe, efficient, fiscally responsible treatment.

PATIENT FITNESS FOR SURGERY

Evaluating patient fitness for surgery varies among patients, providers, and institutions, but the process should consider concomitant disease states, medications in use, and risk factors related to the surgical procedure planned. The extent of laboratory studies needed, level of cardiac evaluation and perioperative apnea precaution, and type and extent of imaging, is individualized based on patient characteristics, comorbid conditions, and medications. LC often is performed in less than 1 hour, with patients supine; therefore, appropriate venous thromboembolism (VTE) prophylaxis may include sequential compression devices alone, pharmacologic prophylaxis alone, or both in concert depending on patient characteristics and risks.^{44,45} Antibiotic prophylaxis using a first-generation cephalosporin often is utilized for LC, although recent data suggest that antibiotics are not required for LC in patients at low risk for infection.^{46–48} We recommend a preoperative assessment that is tailored to the physiologic state of individual patients based on their medical history and personal risk factors.

OPERATIVE TIMING

The timing of LC is a factor important to patient outcomes, and timing of surgery relative to both the disease process and

the operating room schedule are significant. LC can become significantly more challenging as the degree of biliary inflammation and fibrosis increases; biliary inflammation makes dissection more hazardous, makes identification of anatomical structures more tedious, and increases the risk of bile duct injury.⁴⁹ Therefore, surgeons caring for patients suffering from acute cholecystitis best serve the needs of their patients by intervening early, within 72 hours according to most authors.^{50,51} When early intervention is not possible, a next-best approach is to provide antibiotic coverage and supportive care, and allow the acute disease process to regress during a 6–12 week cooling down period, and to then approach LC electively.⁵² Patients who develop recurrent acute cholecystitis during this cooling down period, and require treatment before sufficient resolution of biliary inflammatory fibrosis, may require LC, open cholecystectomy, or subtotal cholecystectomy, or percutaneous, laparoscopic, or open placement of cholecystostomy tubes as treatment.^{19,53–55}

Because biliary inflammation and inflammatory fibrosis can prove challenging and increase the risks of bile duct injury, whenever possible, it is advised that LC for acute cholecystitis be added to the operating room schedule at a time of day when redundant staff, more experienced surgeons, and imaging support all are available readily in order to diminish the likelihood of operative complications.^{56,57} The Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) Safe Cholecystectomy Task Force conducted a nominal group Delphi process that identified factors important to the reduction of bile duct injury during LC.² Several of the critical safety factors identified by this Task Force that may serve a role in improving the safety of LC are (1) calling for assistance from more experienced surgeons when necessary and available; (2) utilizing biliary imaging techniques like IOC liberally; (3) employing adequate assistance to provide excellent retraction, exposure, and visualization; (4) placing cholecystostomy tubes or pursuing other alternatives to complete resection when necessary; and (5) transferring patients to a facility capable of providing a more advanced level of care when necessary and available. Even in very well-equipped institutions, each of these measures might be quite difficult to implement during LC scheduled in the operating room during the overnight; staffing par levels are reduced such that adequate numbers of skilled assistants are less likely, one surgeon typically is on call and backup may or may not be available and may or may not have additional biliary expertise to share, and many important support services from other departments, like radiology and therapeutic endoscopy, are less available. Whether scheduling urgent LC during the daytime schedule is feasible will be determined by individual institutional logistics and patient circumstances, but when possible, we advise this approach.

CONTRAINDICATIONS TO LAPAROSCOPIC CHOLECYSTECTOMY

Only two absolute contraindications to LC have been identified; the inability for the patient to tolerate general

anesthesia, and uncontrolled coagulopathy.^{58,59} Relative contraindications are modified as techniques evolve, individual and aggregate experience grows, and equipment is developed or acquired; there may be some variations among institutions and surgeons regarding relative contraindications to LC. Relative contraindications to LC are considered the same as contraindications to laparoscopy in general; generalized peritonitis, septic shock, severe acute pancreatitis, lack of necessary equipment, lack of surgeon expertise, scarring from previous abdominal operations that prevents safe abdominal access or progression of the procedure, and advanced cirrhosis with hepatic failure, among others.⁵⁹

OPERATIVE TECHNIQUE

Patient positioning

LC begins with the fully monitored and anesthetized patient positioned supine on a well-padded operating room table capable of positional adjustments that include at least reverse and standard Trendelenburg and left-sided rotation. Operating room tables additionally should be capable of being lowered in height sufficiently to support an ergonomic surgical approach. Surgeon preferences vary with respect to patient arm positioning; some prefer both arms to be padded and tucked at the sides, while others tuck the left arm and support the right arm at subacute angles on a padded arm-board.⁶⁰ We prefer to tuck the right arm and support the left arm at a subacute angle on a padded arm-board. This provides ample room to approach the right side with the C-arm mobile image intensifier when performing fluorocholangiography, and allows for fluoroscopic guidance during laparoscopic common bile duct exploration without displacing the operating surgeon. Tucking the right arm also provides room for an assistant to stand above the surgeon to provide retraction should conversion to an open operation become necessary. There may be unique positioning considerations for novel approaches, like robot-assisted cholecystectomy, dictated by the unique requirements of that surgical platform.

Abdominal access

Once the abdomen has been widely prepared with sterilizing solution, draped, necessary equipment brought to the field, and any required operative pause or time-out conducted, laparoscopic abdominal access is gained. There are three major techniques for gaining abdominal access; percutaneous Veress needle placement, open introduction of the first port using the Hasson technique, and direct access using an optical trocar placed under visual guidance.^{61–63} Regardless of the approach utilized, it is common practice to administer local anesthetic at sites planned for incision.

The Veress needle can be introduced through a periumbilical incision with the patient in Trendelenburg position to

shift abdominopelvic contents cephalad, directing the needle toward the empty space in the pelvis between the major vessels. It also can be placed off-site in the left upper quadrant with the bed flat or in reverse Trendelenburg position. Abdominal pressure monitoring, a saline drop test, or other method is used to confirm free intraperitoneal placement of the Veress needle; the saline drop test affirms intraperitoneal positioning when saline placed at the needle's hub is drawn through the needle as the abdominal wall is lifted, creating an intraperitoneal vacuum.^{64,65} Low flow insufflation is initiated once appropriate device placement has been confirmed. A trocar is then introduced into the insufflated abdomen, using either a blind insertion technique or optical entry.

The Hasson trocar is placed after creating a periumbilical incision, carrying the dissection through abdominal wall fascia, and entering the peritoneum under direct vision, often palpating with a finger inserted through the incision in an attempt to be assured that no adjacent viscera will be impinged by introduction of the trocar.⁶⁶ It is held in place using fascial stay sutures wrapped around posts on the wedge-shaped acorn through which the cannula slides. Placement of the Hasson trocar, long considered the safest method of abdominal entry, does not assure that bowel injury will not result, but major vascular injury is markedly reduced by using this technique.⁶⁷ High flow insufflation is initiated once the device has been placed.

Direct optical entry is accomplished by placing the 0° laparoscope within the central lumen of a trocar designed with a cone-shaped tissue-separating tip, focusing on the transverse ridge at the tip of the device, and gently twisting 30°–45° left and right as the device is advanced through a previously fashioned skin incision.^{61,68} Layers of the abdominal wall are seen separating as the trocar is inserted, and high flow insufflation is initiated once the device has been placed.

Each of these techniques, and several novel methods, has been used safely to provide abdominal access for laparoscopic surgery.^{61,69–71} However, each method also has been associated with unintended organ injury, significant hemorrhage, and death resulting from bowel perforation, major and minor vascular injury, and solid organ penetration.^{72–74} Great care is required in achieving abdominal access for LC.

Retraction and exposure

After achieving safe abdominal access, standard four-port LC assumes that three 5 mm ports will be placed with two in the right upper quadrant and another in the epigastrium. A 12 mm port typically is placed in the periumbilical region, although some surgeons utilize a 12 mm port in the epigastrium and a 5 mm port near the umbilicus. The patient typically is placed in reverse Trendelenburg with the table rotated leftward.

Graspers are deployed through the right upper quadrant ports, the lateral one applied to the fundus and the medial

one applied to the infundibulum of the gallbladder. The 30° angled laparoscope is introduced through the umbilical port, and the Maryland or other dissector is deployed through the epigastric port. The surgeon has maximal control when the epigastric and medial right upper quadrant instruments are manipulated by their right and left hands, respectively. The lateral right upper quadrant station is used by the assistant who may also support the laparoscope through the umbilical port, although it is most helpful when a second assistant is available to direct the laparoscope. The assistant retracts the fundus of the gallbladder cephalad, while the surgeon uses bimanual dissection to approach the hepatocystic triangle. The medial right upper quadrant grasper is used to expose anterior and posterior views of the hepatocystic triangle by distracting the infundibulum laterally, and then medially, while the camera assistant maintains a steady, centered view that allows the entire operative field to be seen with the aid of the angled lens laparoscope.

THE CRITICAL VIEW OF SAFETY

The critical view of safety (CVS) popularized by Strasberg and colleagues represents an approach to LC that enhances safety of the dissection and significantly reduces, but does not eliminate, the likelihood of bile duct injury.^{3,75,76} There are three requirements for achieving the CVS: (1) The hepatocystic triangle first must be cleared of all fat and fibrous tissues; exposure of the CBD is not an intended outcome of this maneuver. (2) At least the inferior one-third of the gallbladder must be separated from the cystic plate of the liver, commonly recognized as the flat, fibrous portion of liver bed inferior to the gallbladder fossa. (3) Two structures, the cystic duct and cystic artery, and only two structures should be seen entering the gallbladder (**Figure 70.2**).

Achieving the CVS requires a stepwise approach to dissection of the hepatocystic triangle with which the surgeon must develop great familiarity. Note that we make reference to the hepatocystic triangle, and not the triangle of

Calot. The former is a broad triangular region that serves as the focus of safe surgical dissection in achieving the CVS, whereas the latter served as a guide to the location of the cystic artery during an era when dissection during cholecystectomy was much more limited in extent than what is required for the CVS.

Surgeons differ in their approaches to cholecystectomy; one of us prefers an initial electrosurgical dissection that elevates the gallbladder from the cystic plate first (TJV), while the other prefers an energy-sparing initial dissection of peritoneal vestments aimed at unroofing the hepatocystic triangle and its structures early on (RDF). Regardless of approach, the anterior dissection is initiated with the fundus retracted cephalad and the infundibulum distracted laterally and somewhat caudally; the angled laparoscope is positioned light-cord up to provide a lens-down view of the hepatocystic triangle, but active repositioning to provide the best possible view is essential. Electrosurgical dissection, when utilized, is begun by incising the anterior, and then posterior, peritoneal vestments attaching the base of the gallbladder to the cystic plate, and then switching to blunt dissection of the cystic duct and artery.

Once the gallbladder is retracted as described and visualization of the hepatocystic triangle has been achieved, the anterior peritoneum is grasped in the region of the cystic duct, immediately adjacent to the gallbladder wall, and removed, gently pulling it up toward the liver, not down toward the CBD. This is repeated until the cystic duct and cystic artery have been exposed, and all of the anterior peritoneal vestments have been taken down (**Figure 70.3a**).

The infundibulum is then distracted medially and caudally, exposing the posterior view of the hepatocystic triangle. Similar techniques are used to gently grasp and remove the peritoneum superficially overlying the cystic duct and cystic artery posteriorly, again lifting this tissue up toward the liver, not down toward the CBD or common hepatic duct, beginning immediately adjacent to the gallbladder wall (**Figure 70.3b**). This too is repeated until all of the posterior peritoneal vestments have been taken down.

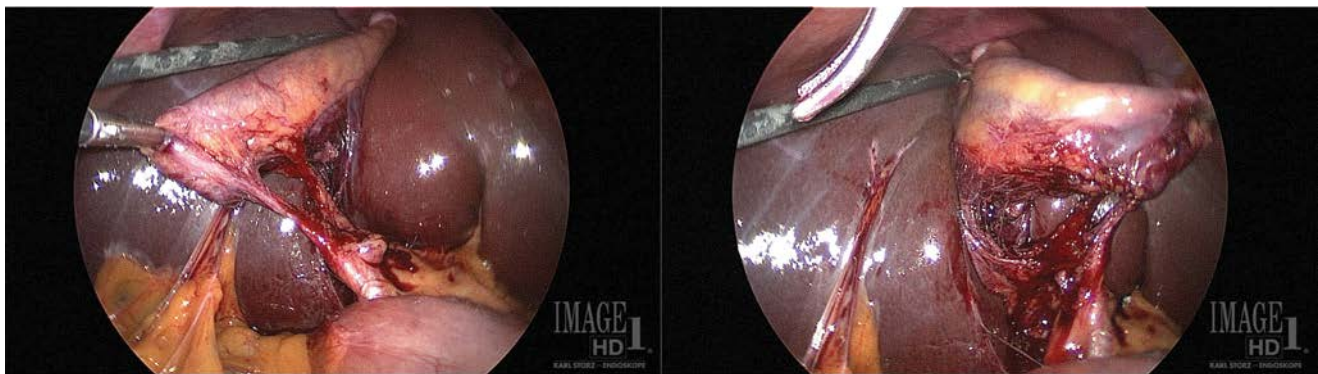


Figure 70.2 Anterior and posterior views of the CVS presented as a doublet photograph. Note complete clearance of the hepatocystic triangle, elevation of the inferior gallbladder from the cystic plate, and confirmation that two and only two structures enter the gallbladder.

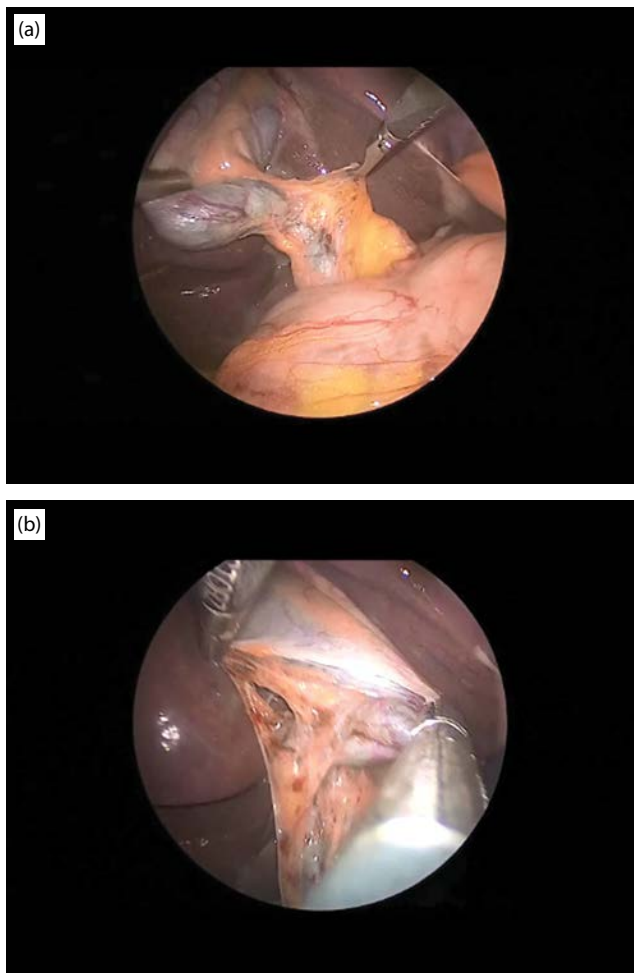


Figure 70.3 Initial dissection of the hepatocystic triangle: (a) anterior peritoneal vestments are removed, exposing the cystic duct and artery; (b) posterior peritoneal vestments are detached; note that movement is directed toward the hepatic parenchyma, not the portal structures.

Alternating between anterior and posterior views now, the cystic duct and cystic artery are clarified through further dissection, stripping the fibrous tissues and remnant peritoneal vestments until just these two structures are seen entering the gallbladder, and the hepatocystic triangle has been cleared of fibrous material as inspected from both anterior and posterior views. The gallbladder is then lifted away from the cystic plate by gently disrupting the anterior and posterior peritoneal attachments on either side of its base and then using an instrument to apply gentle anterior traction to the gallbladder body just above the infundibulum, lifting it toward the abdominal wall (**Figure 70.4**).

Numerous studies have shown that when the CVS approach uniformly is applied, the observed rate of bile duct injury is significantly less than the calculated rate that would be expected based on the general experience in a large series of LC reported separately.^{77–82} The CVS technique, however, has not been shown to eliminate all bile



Figure 70.4 The gallbladder is elevated away from the cystic plate using gentle anterior displacement after dividing the medial and lateral peritoneal vestments.

duct injuries.^{76,83} This notwithstanding, the CVS approach is widely advocated, and the SAGES Safe Cholecystectomy Task Force suggests that surgeons pause after completing the CVS dissection to assess and confirm the identity of important biliary structures before dividing them.² Some have advocated recording intraoperative doublet photographs, combined anterior and posterior views once the CVS has been achieved, and a six-point doublet rating scale has been suggested⁸⁴ (**Table 70.2**).

Once the CVS has been achieved, preparations are made to perform IOC. IOC is discussed more completely in the section “Intraoperative Biliary Imaging”; what follows is a brief description as it relates to continuing and completing LC.

In preparation for IOC, we apply a single clip at the cystic duct–gallbladder junction. The cystic duct then is opened sharply, dilated with an instrument if necessary, and a wire-guided cholangiogram catheter (Fanelli Cholangiogram Catheter Set, Cook Surgical, Inc., Bloomington, Indiana) is introduced with the aid of a cholangiogram clamp. Once the appropriate fluoroscopic image runs have been obtained and interpreted, the grasper first is reapplied to the infundibulum, and the cholangiogram clamp and catheter then are removed. Two surgical clips are applied proximally to the cystic duct and artery under direct vision, and a single clip is placed on the distal artery, and these structures then are divided carefully (**Figure 70.5**). Surgical clips always are placed where their tips and location clearly can be seen; never should the clip applicator be placed around structures and then lowered, compressing additional tissue toward the CBD, before deployment.

Electrosurgical dissection then is used to divide the anterior and posterior peritoneal vestments that define the lateral borders of the gallbladder fossa, as well as the intervening areolar tissues that adhere the gallbladder to the hepatic parenchyma, until the gallbladder remains attached only by thin bands of fibrous tissue at the fundus. The upper abdomen is inspected for hemostasis, and insufflation

Table 70.2 Scoring the CVS

<i>Two structures, and only two structures, entering the gallbladder</i>	
2 points	Two structures, and just two structures, immediately can be identified entering the gallbladder
1 point	Two structures can be identified entering the gallbladder, but there is overlap of duct and artery or a technical limitation like image darkness or soiled lens that interferes with clear interpretation
0 points	Two separate structures cannot be seen entering the gallbladder, either as the result of poor-quality dissection or technical limitations of the image
<i>Elevation of gallbladder from the cystic plate</i>	
2 points	The cystic plate is immediately seen to be clear, with the lower third of the gallbladder elevated
1 point	The cystic plate is seen, but not clearly; other structures overlap it, or the gallbladder has not been elevated sufficiently
0 points	The cystic plate is not visible, either because of inadequate dissection, or because it is obscured by other structures, instruments, clot, etc.
<i>Clearance of the hepatocystic triangle</i>	
2 points	The hepatocystic triangle immediately is recognized as clear, and the cystic duct and artery are immediately recognized as the only two structures present
1 point	Less than the whole triangle can be seen clearly, either as the result of incomplete dissection or technical limitations
0 points	Fibrous or other tissue continues to obscure clear view of the triangle, precluding determination that no other structures remain within the triangle

Note: Achieving five or more points represents adequate attainment of the CVS as documented in doublet photographs; scores less than five suggest unsatisfactory or unclear exposure of the CVS.

Source: Adapted from Sanford DE et al. *Am Coll Surg* 2014;218(2):170–8.⁸⁴

pressures are lowered and the liver bed inspected for bile staining, bile leaks, and bleeding. Any clot is irrigated, aspirating the fluid laterally rather than medially in the operative bed where displacement of surgical clips or damage to delicate portal structures could result.

SPECIMEN RETRIEVAL AND INCISION CLOSURE

The gallbladder is placed within a specimen retrieval pouch introduced through the 12 mm port. Any spilled gallstones are grasped without crushing them and placed in the specimen pouch prior to its closure; it is our recommendation that spilled stones be removed whenever possible. Alternative techniques include placing the gallbladder within a surgical glove introduced into the abdomen, or direct extraction without a pouch, among others.^{85–87}

After abdominal decompression and the removal of all instrumentation, the 12 mm incision is closed at the fascial level and all skin incisions are closed and dressed according to institutional norms.

SPECIAL CIRCUMSTANCES

Obesity

LC has been shown to be safe and effective in obese patients with conversion rates and complication rates similar to those reported for nonobese patient populations. The difficulties reported in performing LC in the morbidly obese include longer operative times, difficulty establishing and

maintaining pneumoperitoneum, diminished angles of view, limited fundic retraction, and difficult fascial closure, among others.^{88,89} Effective pneumoperitoneum is established in obese patients more slowly than in nonobese patients, but adequate operative space still is created.^{90,91} In some cases, the addition of another 5 mm trocar in line with the two standard right upper quadrant ports, provides a useful opportunity for gentle downward retraction of the omentum and colon, enhancing visualization of the gallbladder. When insufflated, the obese abdomen may have an apex that is not aligned with the umbilicus but rather is somewhat closer to the midpoint between the umbilicus and xiphoid. Shifting the umbilical port superiorly to this location, or to wherever in the upper midline the apex of the insufflated abdomen is located, often provides a superb view of the gallbladder and portal region, particularly when angled laparoscopes are utilized as we recommend for all laparoscopic procedures. If fundic retraction is problematic, using the fundic grasper to elevate the body of the gallbladder anteriorly, toward the abdominal wall rather than purely cephalad over the liver, proves useful in some situations. Fascial closure, often difficult through deep subcutaneous tissues, can be augmented by using a suture passing device, such as the Carter-Thomason Laparoscopic Port Closure System (Cooper Surgical, Inc., Trumbull, Connecticut), to place sutures under laparoscopic guidance.

Performing LC in patients who previously have undergone weight loss surgery most often is no different than performing LC in other patients. However, because the success of transoral ERCP is limited in patients who have undergone Roux-en-Y gastric bypass, we recommend that IOC be performed routinely and reviewed carefully

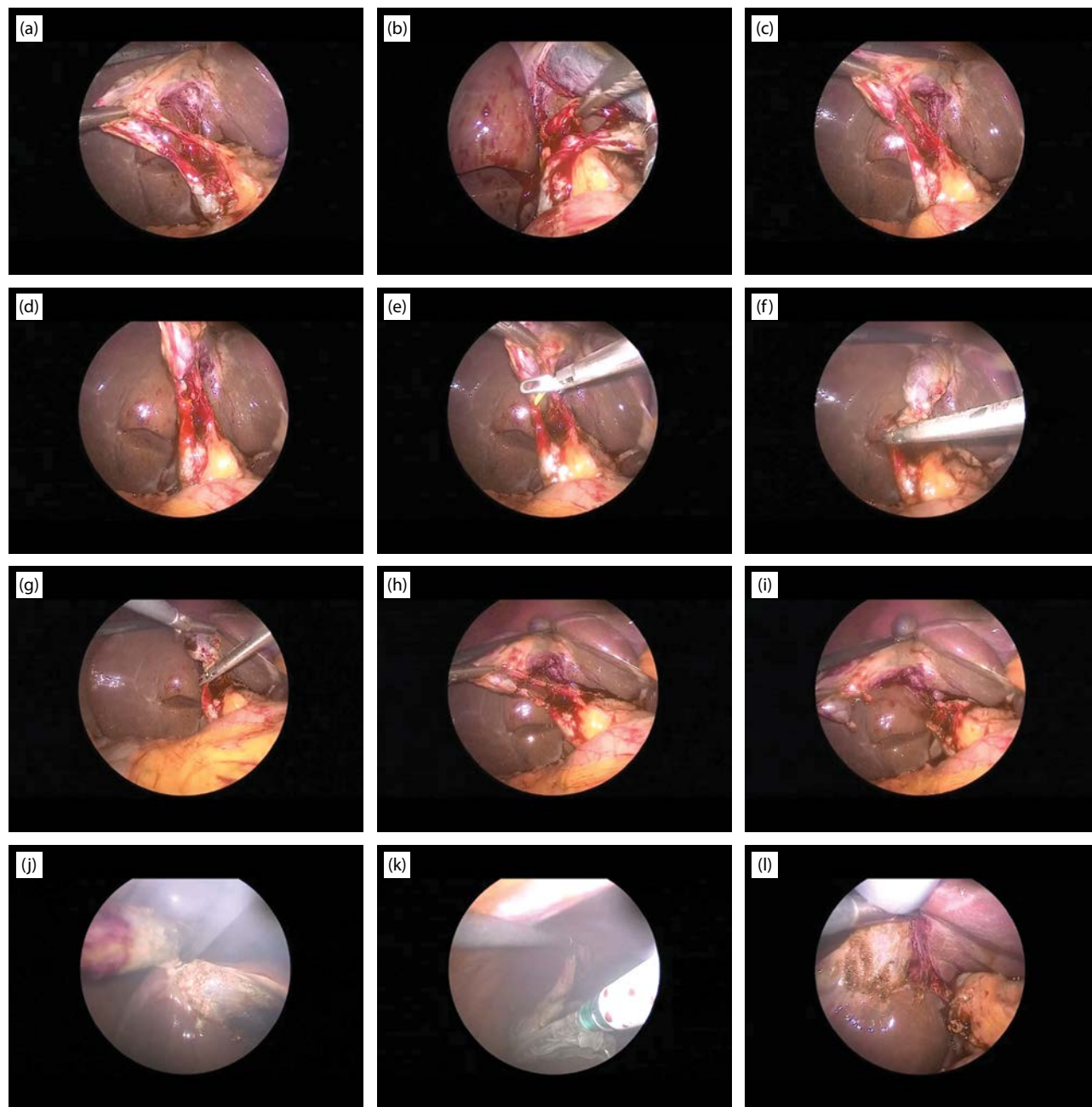


Figure 70.5 Laparoscopic cholecystectomy with intraoperative cholangiography in 12 steps: (a) The anterior CVS is achieved. (b) The posterior CVS is demonstrated. (c) A single surgical clip is placed, occluding the junction of the gallbladder and cystic duct. (d) Cystic ductotomy is fashioned sharply, and valves of Heister are disrupted by gently inserting a single blade of the scissor or dissector. (e) The flushed cholangiogram catheter is inserted through the cystic ductotomy in preparation for intraoperative cholangiogram. (f) The cholangiogram clamp is closed, securing the catheter to the cystic duct; the fundic grasper is secured to the surgical drape using a nonperforating towel clamp, and the infundibular grasper is removed. (g) After completing the intraoperative cholangiogram, the fundic grasper is freed and the infundibular grasper reapplied before removing the cholangiogram clamp and catheter. (h) Surgical clips are applied to the well-visualized portions of the proximal cystic duct and proximal and distal cystic artery. (i) The cystic duct and artery are divided sharply between surgical clips. (j) Electrosurgical dissection is used to remove the gallbladder from the hepatic fossa hemostatically. (k) The gallbladder is placed into a specimen retrieval pouch and withdrawn through the 12 mm port site. (l) After reducing insufflation pressures, the hepatic fossa and portal region are inspected for bleeding, bile leaks, and security of surgical clips.

in this patient population so that any CBD stones are identified and addressed surgically, during the index operation. Management options might include laparoscopic transcystic common bile duct exploration, laparoscopic choledochotomy in the presence of a suitably dilated CBD and an experienced surgeon, or creation of a remnant gastrotomy for intraoperative or postoperative ERCP, among others.^{92,93} Surgeons familiar with choledochoscopy working in institutions with the necessary equipment will find this technique useful in addressing CBD stones. Although unrelated to CBD stones or LC in general, we recommend inspecting for internal hernias if possible when operating on patients who previously were treated with gastric bypass or other predisposing operation.

The tensely distended gallbladder

The finding of a tensely distended gallbladder when beginning LC nearly always is associated with difficulty grasping and safely manipulating the gallbladder; gallbladder perforation, gross contamination with bile, pus, and stones, and tearing of the friable gallbladder wall often result.^{94,95} Gallbladder aspiration should be considered at the outset when tense distension is identified in LC.⁹⁵ Removing the fluid contents of the gallbladder improves the ability to grasp its wall, more safely manipulate the gallbladder intraoperatively to facilitate exposure and safe dissection, and possibly lessen the chance of inadvertent rupture with spillage of gallstones and other contents. Laparoscopic aspiration needles are readily available in many surgical suites, but in their absence, aspiration using large-bore intravenous cannulas, Veress needles, laparoscopic suction cannulas, and other devices has been described.⁹⁶

Severe inflammation

Performing LC during an episode of acute cholecystitis, especially when patient circumstances mandate operative intervention beyond the initial 72 hours of illness, can be extremely challenging. Several nonroutine approaches to this clinical scenario can be useful.

THE TOP-DOWN APPROACH

In the case of severe biliary inflammation, particularly when the gallbladder wall is thickened and inflamed and the distended gallbladder seems indistinct from important structures within the porta hepatis, an antegrade fundus-first or top-down approach often is quite useful.⁹⁷ When severe inflammation precludes safe dissection using the standard approach of isolating the cystic duct, cystic artery, and achieving the CVS, dissection is begun at the top of the gallbladder. The peritoneum adjacent to the dome of the gallbladder is incised electrosurgically, sharply, or using

ultrasonic instrumentation, and the plane between the gallbladder and liver is developed. The lateral peritoneal vestments often can be taken down bluntly in this setting, using gentle pressure applied using a grasper.

The gallbladder is progressively mobilized from the liver bed until its infundibulum has been identified, and the entire gallbladder has been lifted away from the liver. In the setting of severe acute inflammation, this space often is fluid filled, making separation of the gallbladder and liver bed surprisingly straightforward. Most often, at this point, it becomes apparent that there are two structures, and just two structures, entering the now completely free gallbladder. We recommend identifying the cystic duct at this point and performing IOC without placing any clips, either through high cystic ductotomy or by incising the gallbladder wall just above the cystic duct, in order to define biliary anatomy more clearly. Once IOC has defined the location of the common duct and other important structures, and has estimated the length of the cystic duct, it then usually is safe to divide the cystic duct and artery between surgical clips or sutures to complete cholecystectomy. As with any operation in a severely inflamed field, the antegrade approach is associated with more than average bleeding, and liberal use of suction or counted mini-laparotomy pads commonly used during laparoscopic surgery can be useful. If biliary inflammation is so extreme that it precludes safe identification of the cystic duct and important proximal structures, then another approach, such as subtotal cholecystectomy, should be employed.

SUBTOTAL CHOLECYSTECTOMY

If during attempted antegrade cholecystectomy it is not possible to identify with certainty the portal structures even after the gallbladder has been dissected from the liver bed, consideration should be given to performing subtotal cholecystectomy.⁹⁸⁻¹⁰⁰ The oft-interchanged terms *partial cholecystectomy* and *subtotal cholecystectomy* have proven confusing in clinical communications. Recently, it has been proposed that these terms be abandoned in favor of *fenestrated subtotal cholecystectomy* and *reconstituted subtotal cholecystectomy*.¹⁵⁸

Fenestrated cholecystectomy refers to a technique involving near-complete removal of the gallbladder except for a portion of its posterior wall, that which is adjacent to and in contact with the liver bed and portal structures; in this approach, the cystic duct is oversewn from within the neck of the gallbladder. While the risk of biliary fistula is higher using this approach, there is little chance of recurrent cholelithiasis and subsequent recurrent cholecystitis.

Reconstituted cholecystectomy involves resection of the superior portion of the gallbladder, leaving intact or surgically closing the lower body and/or infundibulum, thereby creating a miniaturized gallbladder. We rarely advocate this approach, as often, it simply delays until another time the need for completion cholecystectomy since recurrent cholecystitis is not uncommon.⁹⁸ Additionally, reconstituted subtotal cholecystectomy might incompletely address sepsis or other clinical issues, negatively impacting patient outcomes.

The advantage of this approach that is advocated by some is a lower incidence of biliary fistula as compared with fenestrated subtotal cholecystectomy.

We prefer fenestrated subtotal cholecystectomy in the setting of severe biliary inflammatory fibrosis or whenever a subtotal approach is necessary. After the gallbladder has been dissected safely to its maximal extent, but the hepatocystic structures remain obscured by intense inflammation, the gallbladder wall is divided as closely as is practical to the hepatic parenchyma, leaving all or a portion of the posterior wall attached to the liver bed, and the porta hepatis. The adherent tissues then are inspected internally, searching for the orifice of the cystic duct; any remaining calculi are removed. An IOC is performed by introducing a cholangiogram catheter into the cystic duct orifice to define regional anatomy. The cystic duct is oversewn internally with absorbable suture material placed relatively superficially, into submucosa; mass closure is not employed as this could result in biliary and/or vascular injury, or damage to other adjacent structures. The mucosa of the remnant gallbladder wall is ablated carefully using electrosurgery. It is common to leave regional abdominal drains following this approach.

CHOLECYSTOSTOMY TUBE PLACEMENT

If such extensive biliary inflammation is encountered that neither antegrade nor subtotal cholecystectomy are feasible, consideration should be given to cholecystostomy tube placement.^{101–104} Cholecystostomy can be accomplished by advancing a 10–12 Fr. pigtail catheter into the gallbladder over a straightening introducer, allowing the pigtail to coil as the introducer is removed. Interventional radiologists most commonly place percutaneous cholecystostomy tubes transhepatically, but transperitoneal surgical placement directly into the gallbladder has been shown to be equally effective.^{105,106} If specialized catheters are not available, a mushroom or urinary bladder catheter is placed through a pursestring suture at the dome of the gallbladder after traversing the abdominal wall.

Whenever cholecystostomy tube placement is considered, it is critical first to assess for CBD stones or obstruction, since cholecystostomy will not decompress the CBD unless the cystic duct remains patent. Similarly, in sepsis secondary to emphysematous cholecystitis, gallbladder necrosis, or other terminal extent of biliary inflammation, cholecystectomy must be performed as cholecystostomy will not alleviate the septic focus in these patients.²⁰

Seek expert assistance

The presence of severe biliary inflammatory fibrosis will challenge each surgeon to determine at what point conversion from LC to open cholecystectomy, subtotal cholecystectomy, or cholecystostomy tube placement will be necessary based on their skill, experience, and treatment setting. In these circumstances, it is reasonable to solicit assistance from an experienced colleague if one is available,

or to consider stabilizing the patient and pursuing other measures such as percutaneous or endoscopic approaches if applicable and available, or to transferring the patient to a higher level of care if available.

Reduced port laparoscopic cholecystectomy

Standard LC employs four access ports. Reduced port laparoscopy refers to the group of novel approaches to LC that utilize fewer than the standard four ports, including the performance of LC through a single incision, utilizing one of several approaches popularized in recent years. While it is beyond the scope of this chapter to discuss any of these techniques in detail, three-port, two-port, and single-port LC all have been described by their supporters with varying degrees of success, complications, unanticipated effects, costs, and reasonableness.^{107–114} A recent Cochrane Database Review analyzed data collected from 855 participants in 9 clinical trials comparing standard four-port LC with less than four-port LC.¹¹⁵ These authors concluded that available evidence is of insufficient quality and power to determine any significant clinical benefit in performing LC with fewer than four ports. They further concluded that the safety profile of reduced port LC in these aggregated trials is yet to be established. We do not advocate routine application of reduced port LC.

Robot-assisted cholecystectomy

It is beyond the scope of this chapter to discuss robot-assisted cholecystectomy in any meaningful detail. Studies repeatedly have confirmed the feasibility and safety of robot-assisted cholecystectomy using the da Vinci Surgical Robot (Intuitive Surgical, Inc., Sunnyvale, California).¹¹⁶ However, cost comparisons fall short of justifying the use of robot-assisted cholecystectomy.¹¹⁷ A majority of comparative analyses have concluded that despite the elimination of surgeon tremor, improved imaging, and provision of multiple degrees of freedom of motion, the only measurable advantages conferred by the da Vinci Surgical Robot are surgeon comfort and diminished fatigue. In a systematic review of 560 patients enrolled in six clinical trials, patient outcomes seemed unaffected by use of the da Vinci Surgical Robot for cholecystectomy.¹¹⁸ Robot-assisted single-port cholecystectomy has been compared with the SPIDER Surgical System (TransEnterix, Inc., Morrisville, North Carolina) and single-incision LC.¹¹⁹ Remarkably similar clinical results exist for LC performed using these systems with respect to complications, although surgical time and costs reportedly are less for single-incision LC than for SPIDER-LC or robot-assisted LC.

Until the costs associated with robot-assisted cholecystectomy, including fractionated acquisition and ownership costs, are brought in line with traditional LC, we cannot recommend this as a responsible approach to cholecystectomy.

Section conclusions

Laparoscopic cholecystectomy revolutionized the field of general surgery 30 years ago, and today, remains a relevant topic among surgeons and scientists seeking clarity regarding the most efficient approaches to gallbladder disease. Safety remains of paramount importance, especially in the treatment of acute cholecystitis, where the risk of bile duct injury is high. The principles of safe abdominal access, obtaining the CVS, liberal and routine use of intraoperative biliary imaging, facility with alternative approaches to managing severe biliary inflammatory fibrosis, and enlisting the help of more experienced colleagues when available are the hallmarks of an evolved approach to laparoscopic cholecystectomy.

INTRAOPERATIVE BILIARY IMAGING

Imaging of the biliary tree as an adjunct to LC provides useful anatomic detail and facilitates evaluation for the presence of choledocholithiasis. Additionally, familiarity with laparoscopic cholangiography helps develop the skills needed for laparoscopic CBD exploration, especially when performed using the transcystic approach.¹²⁰ Imaging of the biliary tree with laparoscopic ultrasonography is a useful method for diagnosing CBD stones that has wide applicability in laparoscopic hepato-pancreato-biliary surgery. Newer minimally invasive modalities employ indocyanine green, seeking to define biliary anatomy and to identify pathology through alternative approaches.^{121–123}

Mirizzi first popularized cholangiography in the 1930s and published recommendations on its use in open cholecystectomy in 1937.¹²⁴ A recent Cochrane Database review noted that IOC is 99% sensitive for detecting CBD stones.¹²⁵

Laparoscopic fluorocholangiography has emerged as the most common method of imaging the biliary tree and has replaced static cholangiography in most facilities. Many surgeons perform routine IOC, while others use the technique selectively; in our practice, one of us performs routine fluorocholangiography (RDF), while the other employs selective IOC (TJV). The benefits of routine cholangiography include the following:

1. Discovery of occult CBD stones; between 5% and 15% of patients undergoing laparoscopic cholecystectomy harbor occult common duct stones.^{40–43,126,127}
2. Elucidation of biliary anatomy and confirmation of operative impressions prior to dividing the presumed cystic duct. This may reduce the incidence and/or severity of CBD injury. At least one large population-based study found that IOC reduced the rate of CBD injury from 0.58% to 0.39%.¹²⁹
3. Identification of aberrant ductal anatomy; this too may be important in reducing bile duct injury rates.^{126,130,131}
4. Enhanced opportunities for resident training by teaching skills developed by accessing the cystic duct

routinely during LC, that become transferable when transcystic CBD exploration or choledochoscopy becomes necessary.^{120,127}

5. Enhanced skills for the surgeon and the surgical team.^{2,127}
6. Identification of clinically silent diseases such as cholangiocarcinoma, choledochal cyst, and papillary dysfunction.^{132,133}
7. Development of skills that enable other laparoscopic biliary procedures such as laparoscopic CBD exploration, endobiliary stent placement, or wire placement to facilitate intraoperative ERCP.

The decision to favor selective use of IOC depends on estimating the risk of CBD stones accurately for each patient treated by LC. In patients with symptomatic cholelithiasis, normal preoperative liver chemistries, and no dilation of the common bile duct on transabdominal ultrasound, the incidence of occult common duct stones varies from 0% to 5%, although advanced age is associated with higher risks.^{42,126,128} Proponents of selective cholangiography cite the following benefits compared to routine cholangiography:

1. Reduced time and expense. A recent large review noted an average time of 16 minutes to perform IOC reported in studies published between 1980 and 2011; however, more recent studies report shorter mean time to perform IOC, including a mean of 4.3 minutes in one study.^{135–138}
2. A significant proportion of asymptomatic common duct stones will pass and remain clinically silent.¹²⁸ Identification of these stones can lead to unnecessary intervention, increasing procedure-related patient risks, and treatment costs.^{139–143}
3. Although studies are inconsistent, it has not been shown conclusively that IOC significantly reduces the risk of CBD injury.^{129,135,144}

The controversy between routine and selective cholangiography has continued for decades, because there is good evidence supporting both approaches. Large studies have shown that intraoperative cholangiography is performed in about half of LC.^{145,146} The choice of routine versus selective IOC also depends on local resources and practice patterns. The availability of EUS, ERCP, and magnetic resonance cholangiopancreatography plays a role in the decision-making that underlies one's approach to IOC.

TECHNIQUE AND EQUIPMENT

Ideally, the equipment necessary for IOC should be gathered and assembled prior to beginning LC. The entire team should be wearing protective lead aprons and thyroid shields. Numerous catheters are available for use in performing IOC; we prefer a wire-guided catheter equipped with a trifurcated terminus that allows injection of saline and contrast through separate syringes attached to individual stop-cocks, and provides a central channel for guidewires, stone baskets, and other small-caliber instruments (Fanelli Cholangiogram

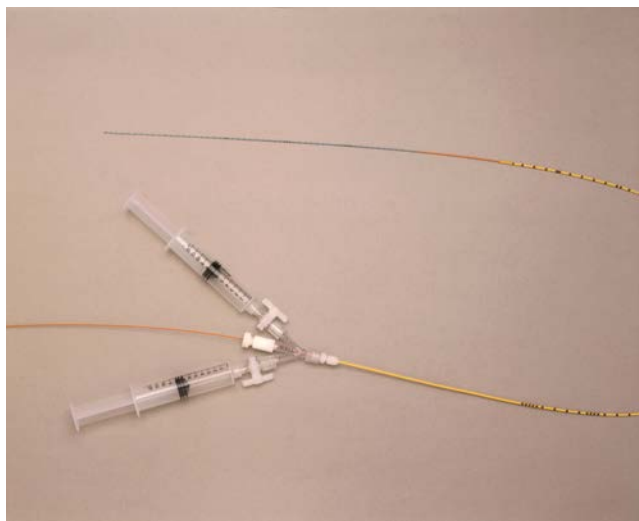


Figure 70.6 Fanelli wire-guided cholangiogram catheter set. (Courtesy of Cook Surgical, Inc., Bloomington, Indiana.)

Catheter Set, Cook Surgical, Inc., Bloomington, Indiana) (Figure 70.6). Care is taken to push the bubbles out of both syringes, and to flush the entire catheter assembly prior to use. The syringe containing saline is used to purge air from the system, while the syringe containing iodinated contrast is used to perform dynamic fluorocholangiography. The contrast initially should be diluted to 50% concentration to increase the sensitivity of detecting CBD stones, but it is commonplace to reserve some full-strength contrast in case darker image penetration is required.¹⁴⁷

Two techniques commonly are used to insert the cholangiogram catheter into the cystic duct. We prefer insertion of the catheter through a cholangiogram clamp, as detailed previously and demonstrated in the Figure 70.5 image series. The clamp and catheter then are inserted together into the abdomen using either the epigastric (RDF) or one of the subcostal trocars (TJV), depending on surgeon preference. The cholangiogram catheter then is advanced 1–2 cm into the cystic duct, and the cystic ductotomy occluded by closing the blades of the clamp around the catheter entry point. Initial injection with saline seeks to test for leaks, confirm low resistance to injection, and free flow into the ductal system.

An alternative technique involves placing a 12- or 14-gauge intravenous catheter through the abdominal wall in a subcostal position directed toward the cystic duct; some catheters are supplied with such access devices. The cholangiogram catheter is advanced into the abdomen through this cannula, into the cystic ductotomy. A clip is used to occlude the ductotomy after inserting the cholangiogram catheter; the guidewire helps prevent occlusion of the catheter during closure of the surgical clip, although it can be useful to employ a cholangiogram catheter with a metal-reinforced tip when utilizing this technique. The advantage of this technique is that the infundibulum can be manipulated with the grasper through the subcostal

trocar, sometimes helpful in navigating the cholangiogram catheter through the valves of Heister. Milking cystic duct stones up through the cystic ductotomy also is useful when insertion of the cholangiogram catheter proves difficult. Novel techniques, such as puncture of the gallbladder infundibulum using a dedicated cholangiogram clamp and needle-tipped catheter have been described for IOC.¹⁴⁸

Once the cholangiogram catheter has been secured, the fundic grasper is removed, or more commonly, anchored to the surgical drapes with a nonperforating Edna or Lorna towel clamp. The infundibular grasper is removed and the laparoscope removed or withdrawn from the abdomen. The operating room table is positioned to accommodate advancement of the C-arm fluoroscopy unit from the patient's right; some surgeons position the table level for IOC, others prefer 15° of Trendelenburg, and still others maintain the reverse Trendelenburg position that had been employed during dissection. Fluoroscopic guidance is used to position the C-arm so that the cystic duct clip is just right of center on the image display, and the image is rotated so that the spine is straight. The ventilator can be turned off briefly as IOC is performed to reduce motion artifact, although the liberal use of fluorocholangiography has reduced the need for this practice. Continuous fluoroscopy is used while contrast is injected slowly, keeping in mind the principles of radiation safety. Cholangiography is considered complete when the entire biliary tree has been filled and the free flow of contrast into the duodenum is demonstrated (Figure 70.7).

If the image is not satisfactory, further steps may be necessary. If contrast does not flow into the proximal biliary tree, the image should be examined to see if the catheter was advanced from the cystic duct into the CBD; repositioning



Figure 70.7 Normal intraoperative cholangiogram; note thin ducts with regular, smooth contours, free flow into duodenum, minimal retrograde filling of the pancreatic duct, and no signs of extravasation or bile duct injury.

the catheter and repeating the IOC may be the remedy. If the catheter position is satisfactory, positioning the table in steeper Trendelenburg position, and tilting the table toward the right, may be helpful. If contrast rapidly flows into the duodenum, inducing spasm of the sphincter of Oddi with intravenous morphine (0.04 mcg/kg) may help opacify the proximal biliary tree by decreasing flow through the ampulla. Another useful technique is to gently, temporarily compress the distal CBD by applying pressure near the duodenum using the laparoscope. Care is taken to keep the laparoscope moving gently to avoid tissue damage, manipulating it under fluoroscopy, encouraging more proximal filling of the biliary tree by increasing drainage pressures. Inability to visualize the proximal biliary tree may be due to a common hepatic duct stone, a clip occluding the common hepatic duct, or a neoplastic process, among other things. If contrast fills the CBD but extravasation is seen proximally, this may indicate the presence of a bile duct injury. A discussion of the management of bile duct injuries is beyond the scope of this chapter, but every surgeon who performs LC should have a bile duct management algorithm in mind based on available resources and personal skills.¹⁴⁹

If contrast does not flow into the duodenum, 1 mg of 0.1% glucagon may induce relaxation of the sphincter of Oddi, promoting contrast flow into the duodenum. If flow into the duodenum still cannot be demonstrated, we advocate flushing 10–20 cc of 1% lidocaine without epinephrine through the cholangiogram catheter into the CBD.¹⁵⁰ Continued obstruction of the distal CBD seen with repeated contrast injection mandates consideration of a CBD stone, tumor, or stricture. CBD stones, the most commonly identified source of distal obstruction, will have a rounded or heterogeneous appearance (**Figure 70.8**); benign strictures usually are smoothly tapered, while tumors appear as an abrupt cutoff with irregular borders.

ALTERNATIVE INTRAOPERATIVE BILIARY IMAGING TECHNIQUES

Although not widely utilized, laparoscopic ultrasound and fluorescence cholangiography using indocyanine green represent alternative methods for defining biliary anatomy and identifying CBD stones. Laparoscopic ultrasound systems are available from a number of manufacturers and generally provide real-time B-mode images as well as color Doppler capability. The flexible linear array probes that typically are designed for laparoscopic applications have a diameter of less than 10 mm to allow placement through standard 12 mm laparoscopic ports. Most probes generate frequencies of 5–10 MHz and provide images of structures 4–10 cm deep.¹⁵¹ During LC, laparoscopic ultrasound can be useful in identifying CBD stones, and for evaluating potential neoplasm of the gallbladder. The laparoscopic probe generally is placed through the umbilical or epigastric port, the choice determined by placement of the 12 mm port itself. The probe is first placed on the anterior aspect of segment IVB/V of the

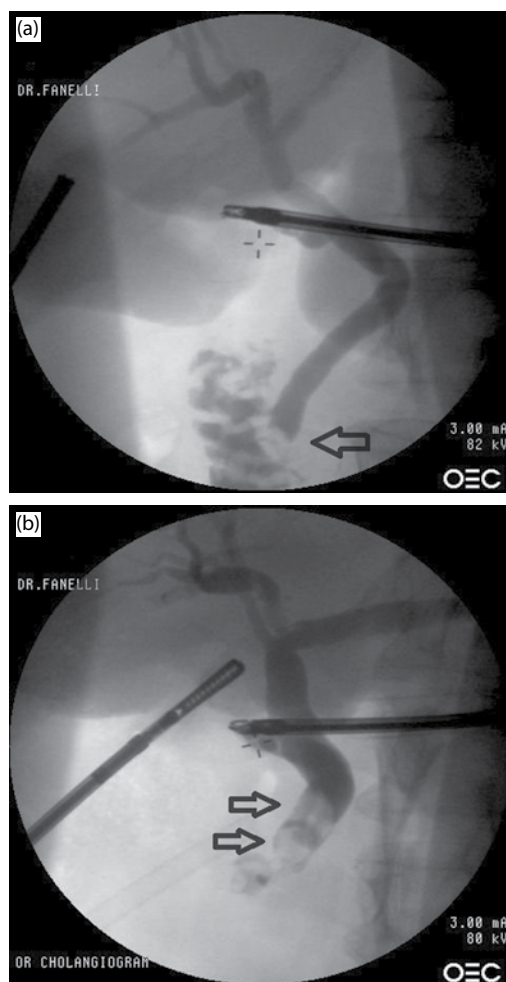


Figure 70.8 Abnormal intraoperative cholangiogram images: (a) note the distal meniscus created by a small impacted stone (arrow); and (b) several large common bile duct stones are identified (arrows).

liver. The common hepatic duct is seen medial to the gallbladder. The common bile duct is examined by elevating the liver and placing the probe directly on the porta hepatis. The retroduodenal and intrapancreatic portions of the bile duct are examined by compressing the duodenum with the probe and by placing the probe directly on the transverse mesocolon overlying the head of the pancreas. Gradual rotation of the probe allows longitudinal imaging without changing stations. The sensitivity of laparoscopic ultrasound in detecting CBD stones is 90%–96%, and the specificity is 100%.^{152,153} Surgeon facility depends on familiarity gained during more than occasional use.¹⁵⁴

Laparoscopic ultrasound is useful also in the laparoscopic management of suspected gallbladder neoplasm. Identification of gallbladder polyps and gallbladder wall calcifications on preoperative imaging can be an indication of malignant or premalignant lesions.¹⁵⁵ Patients may be offered LC if symptomatic, the gallbladder polyp is larger than 7–10 mm, or it exhibits flow on Doppler imaging.

Laparoscopic ultrasound is used to confirm that the interface between the gallbladder wall and liver is intact before proceeding with LC. If a hypoechoic lesion is seen invading the wall of the gallbladder, cancer is suspected and LC abandoned.^{156,157}

Fluorescence cholangiography is an emerging technology that enables noninvasive, real-time intraoperative delineation of biliary anatomy. These methods generally utilize a fluorophore, such as indocyanine green (ICG), and a charge-coupled device camera that filters out wavelengths of light below 810 nm. Since ICG is excreted in bile and fluoresces with a peak wavelength of 830 nm when bound to protein, it can be administered intravenously and used to identify biliary structures.¹²⁸ The sensitivity for identifying the common hepatic duct and the cystic duct CBD junction ranges from 70% to 100%.¹²³ Fluorescence cholangiography using ICG has not been shown effective in patients with occluding CBD stones or impacted cystic duct stones.¹³⁴ We cannot recommend ICG cholangiography in place of contrast IOC or laparoscopic ultrasound presently.

Section conclusions

Intraoperative biliary imaging techniques allow the surgeon to define ductal anatomy, identify CBD stones, and prepare himself or herself with skills needed for more advanced procedures like laparoscopic CBD exploration and choledochoscopy. Although the debate regarding routine or selective use of IOC continues, when IOC is performed, contrast fluorocholangiography almost always is the procedure employed. Laparoscopic ultrasound is particularly useful in the evaluation of patients with gallbladder polyps or suspected neoplasm, and while ICG fluorescence cholangiography looks promising, it continues to have limited utility at present.

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Laparoscopic common bile duct exploration

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INTRODUCTION

Symptomatic gallstone disease is common both in the United States and worldwide. Laparoscopic cholecystectomy is the standard-of-care treatment and over 700,000 cases are performed yearly in the United States alone.¹ Choledocholithiasis, or migration of stones from the gallbladder into the common bile duct (CBD), is a common complication, occurring in 3%–17% of patients undergoing laparoscopic cholecystectomy for cholelithiasis.^{2–4}

During the open surgical era, choledocholithiasis was treated with an open common bile duct exploration, performed at the time of cholecystectomy. However, the management algorithm for CBD stones changed after the introduction of laparoscopic cholecystectomy in the late 1980s and early 1990s. As surgeons were beginning to perform cholecystectomies laparoscopically, relatively few attempted common bile duct explorations in the same setting. As a result, most patients with choledocholithiasis came to be treated using a two-stage approach: With an endoscopic retrograde cholangiopancreatography (ERCP) to remove the CBD stones, and then a laparoscopic cholecystectomy to prevent recurrence of biliary colic and choledocholithiasis. In an analysis of the National Inpatient Sample from 2006, Poulouse and colleagues found that 93% of patients with CBD stones were treated using this two-stage approach, as opposed to only 7% using a single-stage strategy of laparoscopic common bile duct exploration (LCBDE) at the time of laparoscopic cholecystectomy.⁵

Although the two-stage approach of ERCP and laparoscopic cholecystectomy has become the dominant treatment modality, there is level-one evidence that the single-stage approach of LCBDE and concurrent cholecystectomy results in superior patient outcomes. These include reduced lengths of stay and hospital costs, and possibly lower procedure-related complications, most notably pancreatitis.^{6–8} The underutilization of LCBDE despite these clinical advantages

is in part due to a lack of exposure to the procedure during surgical residency. A recent study showed that graduating general surgery residents had performed an average of 0.7 LCBDEs throughout the course of their entire training.⁹

This chapter describes the preoperative evaluation of a patient with symptomatic gallstone disease, including the indications for intraoperative imaging to identify choledocholithiasis. It also details the technical steps of LCBDE, with an emphasis on a transcystic approach using a flexible choledochoscope. Postoperative management and evidence evaluating outcomes after LCBDE are discussed, with a focus on studies comparing LCBDE with the two-stage approach of ERCP and laparoscopic cholecystectomy.

OPERATIVE TECHNIQUE

Preoperative setup and planning

Patients undergoing laparoscopic cholecystectomy should all undergo a thorough medical history and physical examination. Liver function tests and a transabdominal ultrasound should be performed in all patients preoperatively in order to evaluate for the presence of CBD stones. Preoperative magnetic resonance cholangiopancreatography (MRCP) is rarely, if ever, required.

If there is any suspicion for choledocholithiasis based on the patient's history, physical examination, laboratory values, or preoperative imaging (list in [Table 71.1](#)), then intraoperative imaging of the CBD should be performed. This can be done using either intraoperative cholangiogram (IOC) or laparoscopic ultrasound (LUS). Although IOC is the more common modality utilized in the United States, both have shown excellent sensitivity and specificity for detecting CBD stones.^{10–12}

The necessary equipment to perform imaging and LCBDE should be assembled ahead of time, as searching for these instruments intraoperatively adds unnecessary anesthetic

Table 71.1 Indications for intraoperative imaging of the common bile duct to assess for choledocholithiasis

History	Pancreatitis
	Jaundice
	Clay-colored stools
	Dark ("tea-colored") urine
Physical examination	Jaundice
	Scleral icterus
Laboratory tests	Elevated bilirubin
	Elevated transaminases
	Elevated alkaline phosphatase
	Elevated amylase or lipase
Transabdominal ultrasound	Common bile duct diameter greater than 6 mm
	Stones visualized in the common bile duct
Intraoperative findings	Dilated cystic duct or common bile duct
	Stones within the cystic duct

time to the procedure. Appropriate intravenous antibiotics should be administered preoperatively, and sequential compression devices should be applied prior to induction of anesthesia as prophylaxis against venous thrombus formation. If we anticipate an LCBDE will be required, we also place a Foley catheter due to the longer procedure time required.

Port placement and initial dissection to a "critical view of safety"

Either an open Hasson trocar or closed Veress needle technique can be used in a periumbilical location to create a pneumoperitoneum. The patient is placed in steep reverse-Trendelenburg and left side down position. A diagnostic laparoscopy is performed, and the remainder of the laparoscopic trocars are placed under vision. Typically LCBDE can be performed using the standard four-trocar alignment for laparoscopic cholecystectomy: A periumbilical camera port, a lateral right-subcostal port to retract the gallbladder fundus, a more medial right-subcostal port for the surgeon's left hand, and a subxiphoid port for the surgeon's right hand.

The assistant uses a grasper placed through the lateral subcostal port to elevate the gallbladder fundus up and over the liver edge to expose gallbladder infundibulum and allow for subsequent dissection. The surgeon then uses a two-handed technique to retract the gallbladder infundibulum and employ a combination of blunt and careful electrocautery dissection to clear the undersurface of the gallbladder of fibrous and fatty tissue. This is done until a "critical view of safety" has been achieved.¹³ The critical view is composed of three essential elements: (1) all of the fibrous and fatty tissue has been cleared from the undersurface of the gallbladder to fully expose the triangle of Calot, (2) the gallbladder has been dissected off of the liver bed at least one-third of the way up its wall, and (3) two structures (the cystic duct

and cystic artery) are seen passing through the triangle of Calot and entering the gallbladder.¹⁴ Completing a careful dissection to achieve this critical view is the most effective way to prevent common bile duct injuries.

Intraoperative imaging for choledocholithiasis

Once the critical view of safety has been achieved, the surgeon can proceed with intraoperative imaging to confirm the presence of CBD stones, using either IOC or LUS. IOC is performed by first placing a clip on the gallbladder-infundibulum junction and then creating a partial ductotomy in the cystic duct. It is important to keep this ductotomy small and high toward the gallbladder side, in order to prevent avulsion of the cystic duct during subsequent LCBDE. A cholangiogram catheter is then passed through the ductotomy. We prefer to use a 5-French open-tip catheter, passed through an Olsen-type fixation clamp. This clamp should be inserted through the more medial subcostal trocar to facilitate passage of the catheter and subsequent introduction of LCBDE instruments. After the c-arm is positioned, a 50%–50% mixture of saline and contrast is injected while fluoroscopic images are recorded. CBD stones can appear as filling defects, a meniscus sign in the distal CBD, or a lack of duodenal filling with contrast (**Figure 71.1**).

LUS is performed using a specialized probe that is inserted through the subxiphoid trocar. The probe is positioned first over the gallbladder and then moved over the porta hepatis to scan through the CBD. With the probe positioned over the porta, the CBD, hepatic artery, and portal vein can be seen simultaneously as three circular structures in cross section. Stones in the CBD appear echogenic and create black "shadowing" posterior to their location.

Determination of optimal approach for laparoscopic common bile duct exploration

If CBD stones are seen on imaging, the surgeon can attempt to flush them into the duodenum. Glucagon (1 or 2 mg IV) is given to relax the sphincter of Oddi and then several

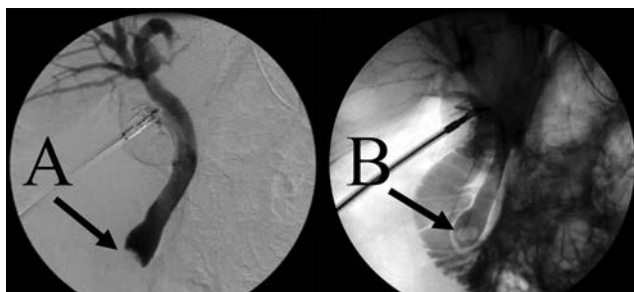


Figure 71.1 Intraoperative cholangiogram images show a meniscus sign (a) and a filling defect (b), both signs of stones in the distal common bile duct.

hundred milliliters of saline are flushed under pressure through the cholangiogram catheter. This technique can be successful for sludge and very small stones but is generally not effective for stones larger than 2–3 mm.

If flushing does not clear the CBD, the first step in LCBDE is to determine the approach: Either transcystic, in which instruments are passed through the existing IOC cystic ductotomy, or transcholedochal, in which a longitudinal ductotomy is made in the CBD (Table 71.2). Because the transcholedochal approach requires making an incision in the CBD, it is more invasive and involves greater risk of CBD injury and stricture. It is therefore reserved for patients with a contraindication to a transcystic approach. These include CBD stones greater than 10 mm in diameter and stones in the common hepatic duct. The presence of five or more CBD stones is a relative contraindication to a transcystic approach, because it is faster to extract multiple stones through a choledochotomy. The one important contraindication to a transcholedochal approach is a CBD diameter of less than 8 mm. Closure of the choledochotomy in a narrow duct will lead to high rates of CBD stricture.

Transcystic laparoscopic common bile duct exploration

Procedure steps and required equipment for *transcystic* LCBDE are presented in Table 71.3.

Wire access

To initiate a transcystic LCBDE, a 0.035" guidewire is passed through the cholangiogram catheter under fluoroscopy (Figure 71.2). Difficulty in wire passage is often encountered at two locations: The valves of the cystic duct and at a CBD stone impacted at the ampulla. These obstructions can generally be overcome by gentle manipulation of the wire

back-and-forth and with application torque to the wire to change the direction of its angled tip. The wire should be passed well into the duodenum, in order to prevent accidental migration out of the cystic duct during the subsequent steps of the procedure.

Balloon dilation

We routinely perform a balloon dilation of the cystic duct in order to facilitate both choledochoscope insertion and subsequent stone extraction, although others omit this step if the cystic duct is large or the CBD stone is small. The cholangiogram catheter and Olsen clamp are removed while holding the guidewire in position using a laparoscopic grasper. A balloon dilator is passed over the wire and through the cystic ductotomy. Standard dilating balloons for this purpose are 4 cm length and 8 mm diameter. The balloon is inflated under fluoroscopy and held for several minutes to ensure complete dilation of the cystic duct valves (Figure 71.3).

Choledochoscope insertion

After dilation, the balloon is removed and the guidewire kept in position with a grasper. The choledochoscope is then inserted by placing the wire through its working channel. To save time, the operating room staff should set up the choledochoscope during the prior steps (Figure 71.4). This involves bringing in a second laparoscopic tower with a light-source and camera box for the choledochoscope. Sterile tubing from a saline bag for continuous irrigation is attached to a side port in the working channel of the choledochoscope. The two laparoscopic monitors, one for the laparoscopic view and the other for the choledochoscopic, are positioned side-by-side over the patient's head.

The choledochoscope is then inserted over the guidewire and gently advanced through the cystic ductotomy. A rubber-padded grasper is used to avoid damaging the scope. During this step, it is important to keep the guidewire straight and taut in order to prevent the choledochoscope from looping inside the abdomen. Once the scope is within the cystic duct, the ductal lumen is kept centered using a combination of scope flexion and torque. The scope is advanced through the cystic duct and into the CBD until the stones are visualized (Figure 71.5).

Stone retrieval and extraction

A wire basket is then passed through the working channel of the choledochoscope. The basket is advanced distal to the stone and then opened. After the basket is deployed, it is slowly pulled backward in order to capture the stone within its wires. This often requires jiggling the basket back and forth when the stone is alongside it, until the stone falls

Table 71.2 Indications and contraindications for transcystic and transcholedochal approaches for LCBDE

Transcystic LCBDE	Transcholedochal LCBDE
Indication	
Stone(s) in the common bile duct	Stone(s) in the common bile duct or hepatic ducts
Contraindications	
Stone greater than 10 mm in diameter	Common bile duct diameter less than 8 mm
Common hepatic duct stones (relative contraindication)	Surgeon not experienced with advanced laparoscopic dissection and intracorporeal suturing
Five or more stones (relative contraindication)	

Table 71.3 Procedure steps and required equipment for *transcystic* LCBDE

Procedural step	Key points	Instruments
1. Cholangiogram	- Perform the IOC through the midclavicular subcostal trocar (rather than the epigastric trocar) - Perform the cystic ductotomy high toward the gallbladder side of the duct	5 Fr open-tip cholangiogram catheter Olsen clamp
2. Use adjuncts to clear common duct	- Give IV glucagon and wait several minutes, then flush with several hundred milliliters of saline - Repeat IOC to assess for clearance	1 or 2 mg IV glucagon
3. Guidewire access	Pass the guidewire through the cholangiogram catheter and advance into the duodenum	0.035" flexible-tip guidewire
4. Cystic duct dilation	- Remove the cholangiogram catheter, holding the wire in place - Pass the balloon dilator over the wire and confirm position fluoroscopically - Inflate the balloon and hold for at least 3 minutes	Balloon dilator Pressure injector
5. Choledochoscope insertion and maneuvering	- Remove the balloon dilator and pass the scope over the wire - Start continuous irrigation through the scope's working channel - Once the scope is within the common duct, the wire can be removed - Use only a padded grasper to manipulate the scope to avoid damaging it	Choledochoscope Saline irrigation (3 L bag or 1 L pressure-bag) Second laparoscopic tower with camera and light cable Padded grasper
6. Stone capture and extraction	- Pass the wire basket through the scope channel - Advance the basket in a closed position past the stone, then open it and "trawl" backward with the basket open to capture the stone - Close the basket around the stone, and slowly remove the scope and stone as a single unit	Endoscopic wire basket
7. Completion IOC	Regardless of findings on LCBDE, perform a final IOC to confirm stone clearance and flow of contrast into the duodenum	Same as initial IOC
8. Cystic duct ligation	If the cystic duct was balloon dilated, use a suture loop rather than clips to ligate it	Suture loop

**Figure 71.2** A guidewire is passed through the cholangiogram catheter and into the common bile duct under fluoroscopic visualization.

to within the center of the basket wires (**Figure 71.6**). The basket is then gently closed to capture the stone.

As the stone is removed, some resistance can be encountered as the stone passes through the cystic duct. As long as an adequate dilation was performed and the stone is no greater than 10 mm in diameter, this resistance can be overcome with gentle traction. Only one stone can be captured with the wire basket at a time, so if more than one CBD is present the choledochoscope must be reinserted and the capture and extraction process repeated.

Completion cholangiogram and cystic duct ligation

Even after all stones are removed and the CBD appears clear choledochoscopically, a completion cholangiogram should be performed to check that contrast flows into the

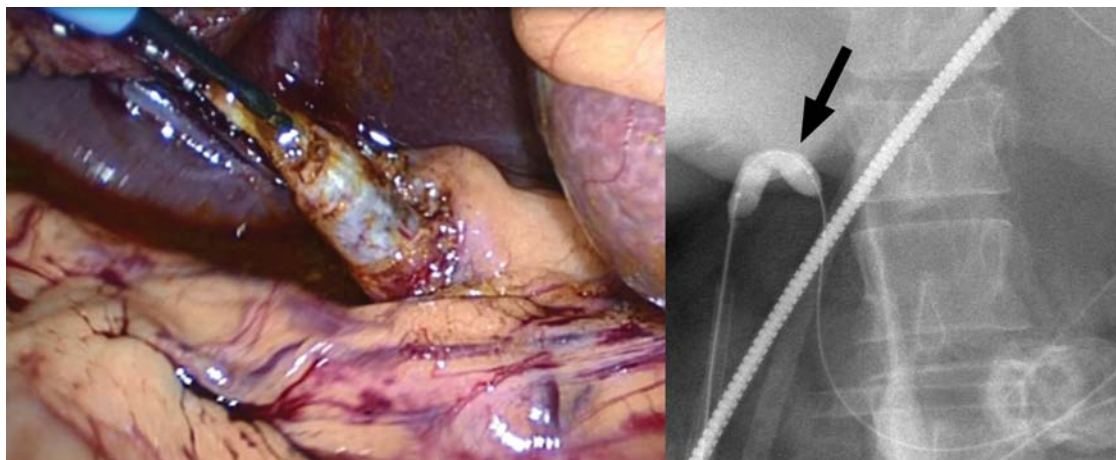


Figure 71.3 A balloon is used to dilate the cystic duct to facilitate choledochoscope insertion and stone extraction. The balloon is inflated with contrast so that its silhouette can be seen fluoroscopically (arrow) to ensure that the cystic duct is uniformly dilated.



Figure 71.4 The flexible choledochoscope is set up with a laparoscopic camera (A) and light source (B) attached to its head. A working channel (C) allows for passage of endoscopic instruments, such as the guidewire and stone basket. Tubing (D) is connected to a side-port of the working channel to provide continuous irrigation through the scope.

duodenum and there are no residual filling defects. Stones that migrated proximally into the hepatic ducts may be missed on choledochoscopy but can be identified on IOC. If the completion IOC is clear, the cystic duct can be ligated. As the duct was balloon dilated, a pre-tied suture loop is used for duct ligation, rather than clips. The gallbladder is then dissected off the liver bed and removed as in a normal laparoscopic cholecystectomy. It is generally not necessary to leave an intra-abdominal drain, unless there is concern regarding the adequacy of cystic duct ligation.

Transcholedochal laparoscopic common bile duct exploration

Procedure steps and required equipment for *transcholedochal* LCBDE are presented in [Table 71.4](#).

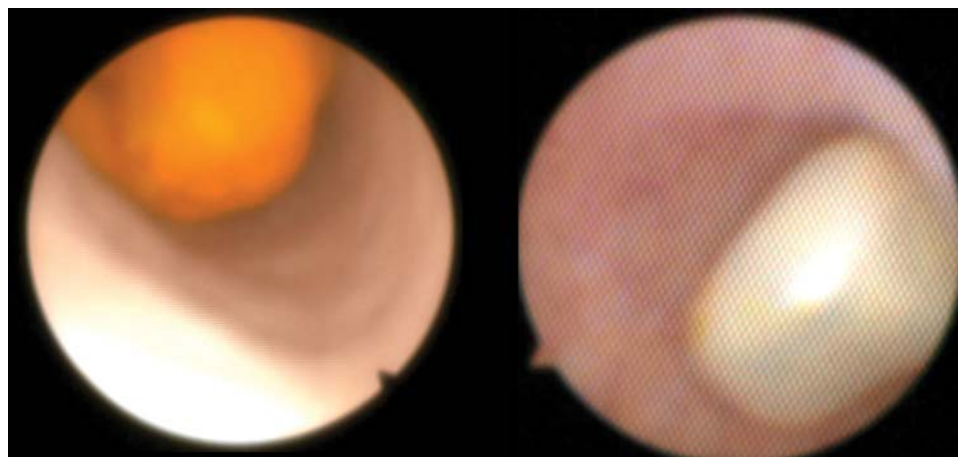


Figure 71.5 Choledochoscopic images from two different cases show single stones in the distal common bile duct.

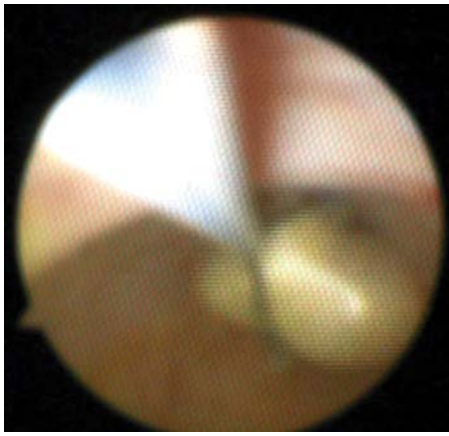


Figure 71.6 A wire basket is passed through the working channel of the choledochoscope and used to capture a common bile duct stone.

Choledochotomy creation

Transcholedochal LCBDE is a more complex procedure requiring advanced laparoscopic dissection and suturing skills. Therefore, it should only be used when a contraindication to a transcystic approach exists and the surgeon is comfortable with the requisite techniques. We generally reserve transcholedochal LCBDE for patients for whom an attempted ERCP has already failed to clear the CBD or patients with anatomy that precludes ERCP (e.g., prior Roux-en-Y gastric bypass).

The first step of transcholedochal LCBDE is to clear an area of the anterior CBD for the ductotomy. In patients with a dilated CBD or scant intra-abdominal fat, this often requires little or no dissection. However, in patients with more fatty tissue overlying their porta hepatis, this dissection can be difficult and has the potential to cause CBD injury or bleeding. The dissection should be kept immediately anterior to the CBD, in order to avoid disrupting its blood supply.

Table 71.4 Procedure steps and required equipment for *transcholedochal* LCBDE

Procedural step	Key points	Instruments
1. Cholangiogram	Perform IOC and determine that a transcystic LCBDE approach is not feasible based on stone size (>10 mm), stone location (hepatic ducts), or number of stones (>5)	5 Fr open-tip cholangiogram catheter
2. Choledochotomy	- After IOC, ligate the cystic duct with clips - Create a longitudinal incision in the common duct at least 1 cm in length, and longer than the largest stone	Olsen clamp Laparoscopic scissors (Potts, straight, or micro-curved) or 11-blade scalpel held with a locking grasper Choledochoscope
3. Choledochoscope insertion and maneuvering	- Use only a padded grasper to manipulate the scope to avoid damaging it - Insert the scope through the ductotomy - Start continuous irrigation through the scope's working channel	Second laparoscopic tower with camera and light cable Saline irrigation (3 L bag or 1 L pressure-bag) Padded grasper Endoscopic wire basket
4. Stone capture and extraction	- Pass the wire basket through the scope channel - Advance the basket in a closed position past the stone, then open it and "trawl" backward with the basket open to capture the stone - Close the basket around the stone, and slowly remove the scope and stone as a single unit	
5. Choledochotomy closure	- If the ductal system is clear of stones and sludge, the choledochotomy can be closed primarily using interrupted sutures - If any stones remain, or if the CBD will need to be accessed later on, a t-tube is positioned in the choledochotomy prior to closure around it	4–0 monofilament absorbable suture Laparoscopic needle drivers
6. Completion IOC	- Regardless of findings on LCBDE, perform a final IOC to confirm stone clearance and flow of contrast into the duodenum - If a t-tube was inserted, perform IOC through it; if not, remove the cystic duct clips to perform it	T-tube (10–14 Fr) Same as initial IOC

A longitudinal incision is then made in the anterior surface of the CBD. This can be done using laparoscopic scissors or an 11-blade scalpel held with a locking grasper. The ductotomy is carefully extended superiorly until it is slightly larger than the estimated size of the largest CBD stone.

Stone extraction

The choledochoscope can generally be inserted directly through the CBD ductotomy using a laparoscopic padded grasper; therefore, it is not necessary to use a guide-wire. Once the choledochoscope is within the CBD, stone capture and extraction using a wire basket are performed in a manner identical to that used during a transcystic approach.

Choledochotomy closure

The choledochotomy is then closed with intracorporeal suturing and knot-tying using interrupted 4–0 monofilament absorbable sutures. Traditionally, surgeons placed a T-tube into the ductotomy closure for postoperative biliary drainage and in case repeat access to the CBD was required. However, recent evidence has shown that T-tube drainage does not improve postoperative morbidity, such as bile leak, cholangitis, or stricture, while it does result in longer operative times and hospital length of stay.¹⁵ After the choledochotomy has been closed, a completion IOC through the cystic duct is repeated to check for residual stones, ensure filling of the duodenum, and check for leak from the choledochotomy closure. We generally leave an intraperitoneal drain after transcholedochal LCBDE to assess for, and potentially control, a bile leak, but drainage is not absolutely necessary if the surgeon is confident in the choledochotomy closure.

Postoperative management

After either transcystic or transcholedochal LCBDE, patients are managed similarly to those undergoing standard laparoscopic cholecystectomy. A liquid diet can be initiated immediately after surgery and advanced to solids as tolerated. We generally keep patients in the hospital for observation overnight and check liver function tests the morning after surgery to ensure a downward trend in their bilirubin level, but it is possible to perform LCBDE on an outpatient basis if the completion IOC is normal. Aside from a standard postoperative clinic visit, no additional specific follow-up or surveillance testing is necessary after LCBDE. Formation of primary hepatic stones after LCBDE and cholecystectomy is rare, especially in the United States.

RESULTS

Morbidity and mortality

LCBDE, whether performed via a transcystic or transcholedochal approach, is safe with low rates of both perioperative morbidity and mortality. A Cochrane meta-analysis pooled data from five randomized controlled trials comparing one-stage LCBDE with two-stage ERCP plus laparoscopic cholecystectomy approaches, and found no difference in terms of mortality with both groups at or slightly below 1%.¹⁶ In that analysis, total morbidity was also similar between the two groups. Major complications such as common bile duct injury and hemorrhage requiring return to the operating room are extremely uncommon after LCBDE, occurring in approximately 1% of patients. Other complications, such as bile leak, wound infection, and those resulting from general anesthesia, occur in 10%–15% of patients.^{6,17} One advantage of LCBDE over ERCP is lower rates of postprocedure pancreatitis, a potentially serious and even lethal complication that can occur in up to 5% of patients undergoing ERCP. After transcholedochal LCBDE, more serious bile leaks can occur if a T-tube drain is placed and becomes dislodged postoperatively. This can result in bile peritonitis, necessitating a return to the operating room. For this reason, we generally avoid the use of a T-tube, unless indicated.

LCBDE fails to clear the CBD, resulting in retained stones in between 5% and 20% of patients. Again, this rate appears similar between LCBDE and an ERCP-based approach. However, if LCBDE initially fails to clear the CBD, the patient can then undergo a postoperative ERCP. The result is that the patient requires two procedures, the same as if ERCP had been utilized preoperatively before laparoscopic cholecystectomy.

Length of stay and hospital costs

LCBDE has demonstrated a clear advantage over ERCP with respect to reducing overall hospital length of stay and costs. The previously mentioned study of the National Inpatient Sample showed an average hospital stay reduction of almost a day, and randomized trials have similarly shown reductions in length of stay between 1 and 3 days.^{5–8} A mean overall savings of \$4,500 was determined in the population study, which adjusted for inflation would equate to \$5,290 in 2015 dollars.

SUMMARY

Although patients with choledocholithiasis are frequently treated by general surgeons, ERCP is most commonly utilized to clear their common duct stones before proceeding to laparoscopic cholecystectomy. This treatment pattern has evolved

despite the fact that there is level-one evidence that LCBDE at the time of cholecystectomy results in improved patient outcomes and decreased costs when compared to a two-stage approach that includes ERCP. It is therefore incumbent upon general surgeons to incorporate LCBDE into their armamentarium of treatment options for patients with gallstone disease, and make LCBDE a standard part of general surgery residency training. If general surgeons can incorporate surgical treatment of CBD stones into their standard practice, outcomes could be improved for tens of thousands of patients with choledocholithiasis in the United States each year.

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Laparoscopic left hepatectomy

YASUSHI HASEGAWA AND GO WAKABAYASHI

INTRODUCTION

Laparoscopic liver resection (LLR) has been previously established as a safe and feasible treatment option for liver tumors with widely recognized clinical benefits (e.g., less blood loss, pain, and analgesic requirement; shorter hospital stay; and improved cosmetic results).¹⁻⁶

During the second international consensus conference on LLR, minor LLR was confirmed as a standard surgical practice. However, it remains in the assessment phase despite being utilized by an increasing proportion of surgeons.⁷ Major LLR is an innovative procedure that is still in the investigative phase with incompletely defined risks. LLR involves peripheral wedge resection and left lateral sectionectomy followed by left hepatectomy (resection of segments 2, 3, and 4) for anatomical accessibility and safety purposes.⁸ This chapter describes the technique for laparoscopic left hepatectomy.

SURGICAL TECHNIQUE

Patient, surgeon, and trocar position



The patient is placed in the supine position. The operator stands to the right of the patient with the assistant and the scopist on the patient's left side. A laparoscopic trocar is inserted through the umbilicus in an open procedure, and the other four ports are placed as demonstrated in [Figure 72.1](#). We always use the flexible scope, which can be used to observe the liver from several angles as well as for safety purposes. The tumor location and vessel variation are confirmed using intraoperative ultrasonography.

Mobilization of the left liver

The round ligament and the falciform ligament are divided initially, followed by division of the coronary

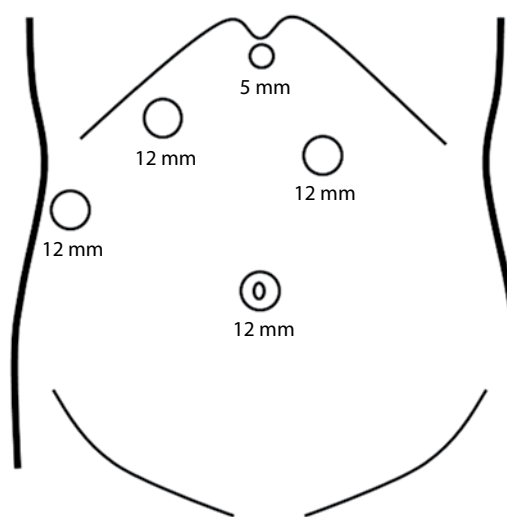


Figure 72.1 Placement of four ports after a laparoscopic trocar is inserted through the umbilicus in an open procedure.

ligament and the left triangular ligament ([Video 72.1](#)). One disadvantage of this procedure is the potential injury to the left hepatic vein (LHV), especially the left edge of the LHV. The LHV is sometimes pulled and tented, so a careless maneuver may lead to the LHV wall being incorrectly identified as a connective tissue. The tissue around the LHV should be carefully manipulated and divided. The inferior phrenic vein is a landmark of the left edge of the LHV.

Next, the left lateral section is either moved to the right side (if possible) or lifted, in order to facilitate division of the hepatogastric ligament. The Arantius ligament is divided near the inferior vena cava in order to visualize the root of the LHV. A cholecystectomy is performed before the hilar approach.

Hilar approach

We can choose the Glissonian approach or individual hilar dissection for the hilar approach. Although individual hilar dissection is the standard technique, the Glissonian approach is also feasible and can be useful for left hemihepatectomy but needs expertise, skills, and knowledge of the liver anatomy.⁷ In both methods, the remnant blood flow should be checked by ultrasonography after ligation of each inflow vessel before cutting.

INDIVIDUAL HILAR DISSECTION

First, the superficial membrane of the hepato-duodenal ligament is cut near the left liver, and in order to expose the left hepatic artery (LHA) (Video 72.2). Once the LHA has been encircled, ensure that it is not the proper hepatic artery. After the LHA has been clipped, confirm blood flow through the right hepatic artery before division of the LHA.

Next, the left portal vein (LPV) is revealed. Some branches of segment 1 as well as the root of the Arantius ligament are subsequently divided. After the LPV has been encircled and clipped, blood flow through the right portal vein should be confirmed. Once the LPV is divided, ensure the absence of narrowing of the right portal vein.

The left hepatic duct is divided once the hilar plate has been exposed by parenchymal transection. Since the posterior hepatic duct goes into the left hepatic duct in 20% of cases, the left hepatic duct should be divided at an appropriate distance from the bifurcation. The risk of injury to the right hepatic duct decreases by cutting the left hepatic duct after exposure of the hilar plate to where the posterior hepatic duct emerges. The left hepatic duct is usually cut along with the hilar plate using an endoscopic linear stapler with white or camel cartridge. However, the kind of stapler should be changed according to the thickness of the hilar plate. Another disadvantage in this step is the potential for injury of the middle hepatic vein (MHV) by the endoscopic stapler, so blind insertion of the stapler should be avoided. If the left hepatic duct can be prepared and visualized in the hilar plate, it can be clipped safely.

Glissonian approach

If the Glissonian approach is adopted, care should be taken in order to avoid injury to the right, posterior, or anterior Glissonian pedicle. The starting point for encircling the left Glissonian pedicle is just distal to the Arantius ligament. Dissection between the Glissonian pedicle and hepatic parenchyma should carefully progress along the Laennec membrane. Once the left Glisson is encircled and ligated, blood flow through the right portal vein and right hepatic artery is confirmed by ultrasonography. The left Glissonian pedicle is also divided once the hilar plate has been exposed by parenchymal transection.

Parenchymal transection, dissection of the left hepatic duct, and dissection of the left hepatic vein

After division of the LHA and LPV, the demarcation line on the liver is revealed and marked by electrocautery (Video 72.3). The intermittent Pringle maneuver is recommended for reduction of bleeding from the liver parenchyma. Pneumoperitoneum should be kept 10–12 mm Hg in order to reduce bleeding from hepatic veins. Additionally, low central venous pressure, the reverse Trendelenburg position, low airway pressure, and low tidal volume contribute to less bleeding from the hepatic vein.

The method of hepatic parenchymal transection can be chosen according to the surgeon's preference.⁹ Hemostatic devices are also chosen according to the surgeon's preference, and we prefer the soft coagulation system with saline irrigation.

First, the surface of the liver is cut by an energy device (ultrasonic scalpel, vessel sealing system, or electric cautery) along the demarcation line. The MHV can be found 1 cm above the bifurcation of the Glissonian pedicle during parenchymal transection. Once the MHV is revealed, the liver parenchyma is transected along the MHV and demarcation line. The MHV is clearly revealed as it is on the border of the right and left hemilivers. Once the parenchymal transection has progressed along the Cantlie line, only a few vessels are found.

After the hilar plate has been exposed by parenchymal transection, the left hepatic duct or the left Glissonian capsule is divided by the endoscopic linear stapler. The parenchymal transection should continue toward the LHV.

The LHV is subsequently divided using the endoscopic linear stapler with a white or camel cartridge. Once the stapler cuts the LHV, the laparoscopic forceps should be placed near the stump of the LHV for easy accessibility to prepare for misfiring of the stapler.

Specimen retrieval

The specimen was extracted using a protective bag through a suprapubic or a previous surgical incision. If the tumor size is not very large, the specimen can be retrieved through the 5 cm incision.

CONCLUSION

We believe that most left hepatectomy procedures can be successfully performed through pure laparoscopy by an experienced surgeon.



VIDEOS

Video 72.1 Laparoscopic left hemihepatectomy—mobilization (<https://youtu.be/k5lwYRphOuA>).

Video 72.2 Laparoscopic left hemihepatectomy—hilar dissection (<https://youtu.be/2BFZ8BPax1s>).

Video 72.3 Laparoscopic left hemihepatectomy—parenchymal transection—specimen retrieval (https://youtu.be/9FAkTqufk_o).

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Totally laparoscopic right hepatectomy

DAVID FUKS AND BRICE GAYET

INTRODUCTION

The practice of laparoscopic liver surgery has grown steadily, and some liver resections currently seem feasible and safe for selected patients and in centers where surgeons are experienced in both liver surgery and laparoscopic surgery. Right hepatectomy is the most frequently performed major liver resection, usually representing one-third of the total number of resections in most series. This is why this operation is often considered a paradigm of liver surgery. Despite significant improvements in the last decades, the risk of such major liver resection is still high with postoperative mortality ranging from 1% to 3% and morbidity rates ranging from 40% to 60%,¹⁻³ at least in Western countries. After this procedure, mortality may reach 0.2%⁴ and morbidity 40%.⁵

Recent reports have underlined that laparoscopy may be associated with such a decrease in blood loss due to the pressure of pneumoperitoneum and the meticulous section of liver parenchyma.^{6,7} The technique of major liver resections is not standardized even through laparotomy. Indeed, countless techniques including those focusing on vascular control⁸ strategy of resection^{9,10} with primary mobilization of the right liver or anterior approach without mobilization, or parenchymal transection¹¹ have been reported.

Two meta-analyses of 15 retrospective studies available representing 847 pooled patients showed that estimated blood loss was significantly reduced in patients undergoing laparoscopic liver resection compared with open liver resection.^{6,7} In this setting, the presence of 12 mm Hg pneumoperitoneum, the magnified vision, and the cautious section of the liver may explain such decreased blood loss.¹² Three main techniques of laparoscopic major hepatectomy are currently available: pure laparoscopy, hand-assisted technique, and hybrid technique.¹³ There is actually no evidence demonstrating that one of these techniques has

any advantage over the others. Our choice was to use the pure laparoscopy to benefit from both the permanent presence of pneumoperitoneum on limitation of blood loss and the smallest incisions possible that account for the various advantages of minimally invasive surgery.

The technique described in this chapter is based on the anterior approach from Liu et al.⁹ but was renamed “the caudal approach” in the study published by Soubrane et al.¹⁴ in the setting of laparoscopy because of the upward dissection and section of liver parenchyma.

ANESTHETIC MANAGEMENT

All patients underwent central venous and arterial catheterization: Two vein catheters and at least one triple lumen internal jugular catheter. Intraoperative monitoring used in this study included a three-lead electrocardiogram, invasive and noninvasive arterial pressure, pulse oximetry, nasopharyngeal temperature, expired CO₂ analysis, inspired oxygen fraction, minute ventilation, mean airway pressure, and respiratory changes of pulse pressure. Anesthesia was induced with propofol, sufentanil, and atracurium. General anesthesia was maintained with a combination of Desflurane, Sufentanil, and Atracurium according to clinical status. After the induction of general anesthesia, intravenous fluids were reduced to 1 mL/kg/h, and before completion of the parenchymal transection, the administration of maintenance fluids was generally reduced to 75 mL/h. The ventilatory parameters were adjusted according to arterial blood gas levels throughout the operation to maintain physiologic pH, and PaCO₂ (7.35–7.45 and 35–40 mm Hg, respectively). Routine antibiotic prophylaxis was given. Upon completion of the operation, all patients were transferred to the surgical department floor in the absence of organ dysfunction.

TECHNICAL DESCRIPTION OF LAPAROSCOPIC RIGHT HEPATECTOMY

General principles of laparoscopic hepatectomy

The main technical steps of laparoscopic hepatectomy are assessing the feasibility of resection with intraoperative ultrasound, vascular control, and parenchymal section. The use of two monitors is recommended. Pneumoperitoneum with an intra-abdominal pressure of 12 mm Hg will decrease hemorrhage during parenchymal transection, which can also be increased up to 15 mm Hg in the event of any bleeding.

Specific instrumentation

The realization of laparoscopic liver surgery requires the following specific hardware (besides the standard equipment of laparoscopic surgery and open surgery equipment available room upon conversion):

- One optical at 0° or 30°, or one flexible optical
- One unit of laparoscopic intraoperative ultrasound
- One liver retractor
- One adjustable cutting linear stapler with several vascular refills
- One plastic bag for extraction
- Several Hemo-Lock clips

To ensure the dissection of the vessels and bile ducts and intraparenchymal parenchymal transection, various specific methods can be used (new instruments using different types of energy to dissect the parenchyma, or coagulate vessels in the closing time of hepatic transection):

- Dissection: dissector harmonic (or ultrasonic), Thunderbeat

Patient positioning

A low lithotomy, that is, “French position,” with both the legs abducted at the hip and flexed at the knees and the patient in reverse Trendelenburg position is preferred. Other routine precautions like adequate padding of the pressure points and thermal covers for the exposed limbs should be followed.¹⁵

Trocar placement

It is difficult to describe a universally acceptable trocar position because of minor variations needed pertaining to each case. Five trocars are introduced, the optical trocar to be located high enough to access the hepatic dome. Hand assist ports can be helpful especially in case of emergency situations like bleeding for surgeons with minimal expertise in advanced laparoscopic procedures.

Ultrasound

An important instrument in liver resection is an intraoperative ultrasound (IOUS). Both in open and laparoscopic liver surgery, ultrasound of the liver is performed for identification of other lesions and to confirm the relationship of the lesion with the portal and hepatic veins.

During the laparoscopic approach, one of the main risks during the hepatic transection phase is to lose the good plane making IOUS absolutely mandatory. Performing a laparoscopic ultrasound of the liver can be a challenging procedure if one has only a rigid device. In right hepatectomy, IOUS aims at identifying the position of segment VIII draining vein into either middle hepatic vein or directly into inferior vena cava, which might avoid unnecessary bleeding.

Mobilization of the liver

Once resectability has been confirmed with ultrasound, the falciform ligament may be left intact or taken down depending on how the liver hangs; it is usually beneficial to leave it intact. The ligamentum teres is retracted as mentioned earlier to expose the porta hepatis. As opposed to left hepatectomy, in laparoscopic right hepatectomy, the liver is retracted cranially and medially with the self-retaining liver retractor after an umbilical tape is placed around the porta hepatis. The right lobe of the liver is mobilized after the parenchymal transection by dividing the right aspect of the coronary ligament and the right triangular ligament.¹⁵

Hilar dissection and control of hepatic inflow

As in a cholecystectomy, the cystic artery and duct are dissected and ligated, but the gallbladder is not initially dissected off of the liver bed, so that it can be used as a handle to retract the liver during the procedure. The porta hepatis is dissected cranially starting from the origin of the cystic duct. The common hepatic duct is dissected until the convergence of the right and left hepatic ducts is found. Any arterial branches to the biliary tree are ligated and transected. The biliary tree is then retracted medially at the confluence of the right and left main hepatic ducts to expose the right hepatic artery, which often bifurcates early into anterior and posterior pedicles. At this point, the right hepatic artery and/or its branches are ligated and transected. The search for a right hepatic artery arising from the superior mesenteric artery is systematic. The portal vein is then dissected until its bifurcation is found. The right portal vein is mobilized for several centimeters, and a small piece of Surgicel is placed for oozing. Dissection continues until a clip is applied across the vein. After the right trunk is transected, the portal vein retracts medially, and the right bile duct is identified above the confluence of the right and left main hepatic ducts. The right duct is then ligated and

transected; care must be taken to identify its anterior and posterior branches if present.

In open liver surgery, inflow control (Pringle maneuver) is a tool to decrease blood loss. It is often used in major resection. In laparoscopic liver resection, it is feasible to obtain inflow control by performing a Pringle maneuver. Although it can be useful, it is not a standard procedure as the pneumoperitoneum (pressure at least 12 mm Hg) decreases hemorrhage during parenchymal transection. We advise getting experience performing a Pringle maneuver, at least in the beginning of laparoscopic liver surgery. In our experience, we have never had to control the outflow, and dissection of the suprahepatic area before the transection seems quite dangerous with a risk of vascular tear, especially between the vein and the IVC. The falciform ligament is cut to the anastomosis of the hepatic veins into the inferior vena cava. The standard approach involves dissection of the pedicle at the hilum into the hepatic parenchyma, with a separate section of the hepatic artery, portal vein, and hepatic duct rights. With another mode of access, Glissonian intrahepatic, and possible laparoscopy, some authors would avoid the risks associated with anatomical variations with a ligature of intrahepatic structures without a separate dissection. Finally, a hemi-liver ischemia by clamping block without dissection of the pedicle of the rights to the bifurcation in the hilar vessels technique appears to be safe in laparoscopy.

Parenchymal dissection

In both open and laparoscopic surgery, different techniques are described for parenchymal transection: electrosurgical devices, bipolar forceps, thermofusion, ultrasound scissors, ultrasound dissector, the clamp and crush method (Kelly clamping), and staplers. No single method has proven to be superior for parenchymal dissection, and as in open surgery there is no consensus on the preferred technique. However, in laparoscopic surgery electrosurgical, Cavitron Ultrasonic Surgical Aspirator (CUSA) and stapler devices are mainly used. All have their (dis)advantages; after our experience with several cases with CUSA and bipolar, we have moved to ultrasound scissors and bipolar. When using bipolar forceps, avoid contact of the bile duct with both the limbs of the forceps together to prevent bile duct injury. When using the ultrasound scissors, that is, Harmonic, Sonosurg or Thunderbeat, always remember to keep the active blade away from major vascular structures and bile duct.¹⁵

Parenchymal section is performed in this case after the time of pedicle ischemia line. There is no control of the right hepatic vein. Segmental glissonian pedicles and hilar plate are cut at the base of the hilar plate (after application of absorbable sutures or clips to end absorbable suture). The posterior portion of the right lobe is cut with exposure, clipping, and section veins draining segments 5 and 8 to the middle hepatic vein. The section of the junction between and right lobe segment 1 is made to harmonic scalpel, exposing the lower part of the retrohepatic vena cava.

Control of hepatic outflow

The IVC is dissected in a cranial fashion toward the middle and right hepatic veins by retracting the liver medially, if possible. All perforating vessels are controlled using bipolar cautery, and then transected. Any major accessory draining veins for segments V and VIII are identified at the initial ultrasound exploration. Once the right hepatic vein is exposed posterior to the liver, the retrocaval ligament is incised to permit better access to the lateral aspect of the right hepatic vein. The retrocaval ligament appears consistently in patients and attaches the posterior aspects of the liver to the tissues behind the IVC. Sometimes the ligament is replaced by vascular prior to parenchymal division and is then anticipated and controlled with clips or monofilament nonabsorbable suture ligation during transection. At the completion of parenchymal division, the last remaining attachment is the right hepatic vein. Sometimes a laparoscopic modification of the liver hanging maneuver as described by Belghiti et al.³² may be useful to enhance the visualization of the vascular structures and facilitate orientation for division of the parenchyma. This technique can be performed by passing an umbilical tape or a pediatric nasogastric tube between the right and middle hepatic veins and between the posterior aspect of the liver and IVC and retracting laterally, thereby lifting the right hepatic lobe off of the patient's diaphragm. An advantage of performing this technique laparoscopically is that it can be performed under direct vision, something that is not possible with an open procedure. If the right hepatic vein cannot be adequately dissected via an extrahepatic approach posterior to the liver, it can be approached intraparenchymally. Vascular staplers are used with the vascular clamp present after circumferential dissection of the vein is complete. Always have the vascular clamp ready and under vision intracorporeally when using the stapler devices. At the end of the procedure when using vascular staplers, there is always a chance of error leading to unnecessary exsanguination. A few safety tips to avoid such events include the following: Create adequate space around the major veins before introducing the vascular staplers, and when using the staplers, never pull on the hepatic veins, which might avulse the vein from IVC.

Hemostasis, drain and specimen extraction

The best way to have proper hemostasis is to control the bleeding points with bipolar cautery rather than to use too much hemostatic agent. Too much hemostatic agent can also mimic an abscess in the follow-up CT scans. We use a drain only in cases with high risk for postoperative bleed or bile leak, which is decided by the difficult intraoperative course. The procedure ends with the extraction of the specimen using retrieval bags through a suprapubic or periumbilical incision if a hand assist system is placed. As previously mentioned, releasing the intra-abdominal adhesions

at the beginning of the procedure will ease the specimen retraction at the end of the procedure.

THREE-DIMENSIONAL VISUALIZATION

One of the major limitations of conventional laparoscopy is lack of depth perception and tactile feedback. Visual information is crucial for performing laparoscopic surgery, and keeping this in mind, improving the optical system has been the goal of associated industries and researchers for years. Besides increasing the resolution of applied camera systems,^{16–18} three-dimensional reproduction of the operative field is the second mentioned approach in this field and is supposed to overcome most of the limitations currently experienced with conventional laparoscopy.^{16–19} Although in recent series 3D visualization was found to reduce errors and speed the completion of laparoscopic tasks,^{20–21} most of those studies were *ex vivo* laparoscopic tasks performed in experimental setup.

In a recent article comparing 3D visualization to high-definition two-dimensional (2D) visualization in laparoscopic liver resection, we showed the superiority of the 3D visualization in terms of operative time, resulting in faster surgery.²² The 3D system gives a better depth perception that cannot be achieved with traditional 2D systems, without any complaints about visual strains. Depth perception and hand-eye coordination were excellent with the 3D imaging system, leading to accurate and swift dissection as well as better intracorporeal knotting to achieve bleeding control or biliary suture, without compromising the safety and operative time. Hence, this better visualization could reduce some intraoperative incidents, particularly during parenchyma transection. Even though blood loss was not significantly different between the two groups, we believe that this difference could become apparent with larger studies.

POSTOPERATIVE COMPLICATIONS

Laparoscopic liver resection could help to reduce postoperative morbidity. In addition, the laparoscopic approach results in decreased abdominal wall trauma, as only five or six port incisions are performed, and the resected specimen is usually extracted through a Pfannenstiel incision. In this context, decreased postoperative pain and early postoperative rehabilitation may provide improved recovery,²³ leading to a reduced length of hospital stay. In a recent article, intraoperative bleeding and ablation or resection of tumors in the remnant liver appear to be associated with postoperative complications. Interestingly, intraoperative bleeding has already been identified as a risk factor for postoperative morbidity after laparoscopic major hepatectomy. In a series of 300 laparoscopic liver resections including 133 of laparoscopic major hepatectomy, Cannon et al.²⁴ reported that the need for transfusion was the only independently significant

predictor of complications. A study²⁵ of 450 patients who underwent laparoscopic or open major hepatectomy showed that open hepatectomy, intraoperative blood transfusion, and blood loss were all independently associated with an increased risk of any type of complication. In this setting, a more frequent use of vascular clamping might reduce intraoperative blood loss.

LEARNING CURVE

The learning curve is defined as the improvement in performance over time or the change in the ability to complete a task until failure is reduced to a constant minimum acceptable rate.^{23,26,27} The learning curve of a pioneer surgeon who is technically proficient or has advanced training in complex minimally invasive surgery techniques will be different from that of a novice surgeon.²³ The level of both laparoscopic and liver surgical experience at the beginning of laparoscopic major hepatectomy (LMH) is essential when evaluating the effect of the learning curve. Given that LMH is a technically demanding procedure, the surgeon should have advanced prior experiences in both open liver resection and laparoscopic procedures, such as upper gastrointestinal and colorectal surgery, before starting LMH. Although some articles have reported improvement of results during the second half of surgeons' experience in laparoscopic minor hepatectomy,^{28,29} the learning curve has never been studied for LMH. Laparoscopy was considered for almost all major hepatectomies in the authors' institution. Our study clearly suggests a learning curve effect due to technique improvement and standardization, especially for parenchymal transection, which represents the most difficult part of laparoscopic liver resection. During the 15-year interval starting in 1998 and ending in 2013, many new devices have been developed, including ultrasonic scalpels, sealing devices, coagulation systems, and staplers, and these have facilitated expansion of the indications. In the authors' institution, CUSA has never been used, and tissue dissection and hemostasis were performed with an ultrasonic dissector, first SonoSurg, then Harmonic Scalpel, and finally Thunderbeat, with frequent use of the Gayet bipolar forceps. Even though these devices do not seem to improve the quality of transection in open surgery, difficulty in controlling potential bleeding during parenchymal transection warrants their use in laparoscopy. Nevertheless, the present study shows that the speed and ease of transection improve with experience, with a significant decrease in the duration of surgery over time.

ECONOMIC OUTCOMES

Three studies reported financial outcomes for laparoscopic major hepatectomy.^{29–31} In the report by Koffron et al.²⁹ one of the pure laparoscopic, hand-assisted, and laparoscopy-assisted methods was used for minimally invasive right

hepatectomy. The results demonstrated cost-savings in the minimally invasive group. Because of the time savings in the laparoscopy-assisted group, the higher device costs in the laparoscopic group were balanced with the longer operating room charges of the open surgery group. Because a learning period is necessary for laparoscopic major hepatectomy, Lin et al.¹³ assume that the hospital courses of patients might be more complicated in the early period, while a single institute is adapting this technically difficult procedure; thus, the favorable fiscal outcome could be abolished in this early period. As the procedure gains more acceptance worldwide, the economic issue could be addressed further to demonstrate that different financial feedback might be seen with different indications (benign versus malignant) or different time frames (early versus late period), whereas a single institute integrates laparoscopic major hepatectomy into their surgical offering.¹³

CONFLICTS OF INTEREST

DF has no conflict of interest. BG received royalties for “Gayet bipolar forceps” (MicroFrance BG-CEV134, Medtronic, Minneapolis, Minnesota).

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Laparoscopic hepatectomy: The Glissonian approach

MARCEL AUTRAN CESAR MACHADO

INTRODUCTION

The Glissonian approach was established by Galperin et al.,¹ Takasaki et al.,² and Launois et al.³ We published a simplification of this technique to facilitate selective clamping of Glissonian pedicles within the suprahilar area.^{4,5} Based on small incisions on anatomical landmarks, it allowed a straightforward control of highly selective Glissonian pedicles without hilar or parenchymal dissection and with no need for ultrasound or cholangiography guidance.^{4,5} These innovative techniques made possible tailored liver resection by removing only the liver segments involved by the underlying disease. We have routinely used it for open liver resections since 2001. With the increasing use of laparoscopic liver resections, it seemed natural to use the Glissonian approach to perform laparoscopic liver resections.^{6,7}

The purpose of this chapter is to give a systematic description of the Glissonian approach for laparoscopic anatomical liver resection.

BASIC PRINCIPLES

At laparoscopy, the abdominal cavity is thoroughly examined to rule out distant and/or extrahepatic metastasis. After that, intraoperative ultrasound is used to ascertain tumor location and its relationship with major intrahepatic vessels and to identify tumors that could be unnoticed by preoperative imaging studies. Liver transection is performed within the ischemic area, determined by previous control of the corresponding Glissonian pedicle that is performed after division with an endoscopic linear stapler. The Pringle maneuver is not routinely used. The liver is transected with bipolar forceps with saline irrigation. A surgical specimen is retrieved through a suprapubic incision, inside a plastic bag. Prevention of deep

venous thrombosis is necessary because operative time can be prolonged. Mechanic sequential compression is routinely used.

RIGHT LIVER: PATIENT POSITION AND TROCARS PLACEMENT

Patients are placed in a left semilateral decubitus position and in the French position, with legs spread apart and bent at the knees with the surgeon standing between patient's legs. Four trocars are used.

Anatomical landmarks used for laparoscopic Glissonian approach

In order to reach Glissonian pedicles from the right liver, we use three small liver incisions around the hilar plate according to specific anatomical landmarks.^{4,6}

A small (3 mm) anterior incision is made in front of the hilum (shown at A in [Figure 74.1c](#)). A second incision (B in [Figure 74.1c](#)) is performed on the right edge of the gallbladder. A third incision is made perpendicular to the hepatic hilum in segment 7, where it connects to the caudate lobe (C in [Figure 74.1c](#)).

Right hemihepatectomy (segments 5, 6, 7, and 8)

Control of the main right Glissonian pedicle is achieved with two small incisions. A large laparoscopic vascular clamp is introduced through those incisions (A and C) to occlude the right main Glissonian pedicle ([Figure 74.2b](#)). Ischemic delineation of the right liver (segments 5, 6, 7, and 8) is obtained ([Figure 74.2e](#)) and is marked along the liver surface with

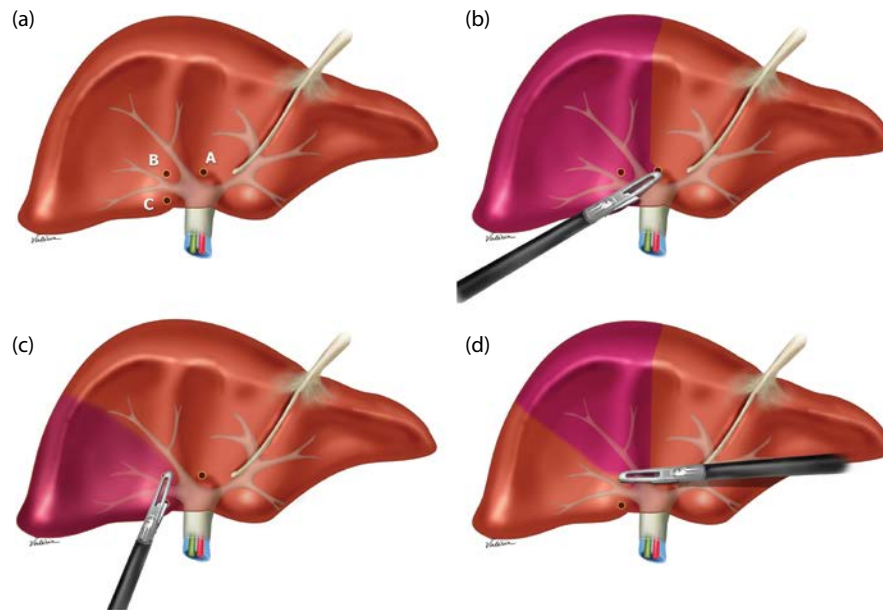


Figure 74.1 Intrahepatic Glissonian access for laparoscopic right liver resections. (a) Incisions for the intrahepatic approach of Glissonian pedicles. A. Anterior incision in front of the hilum. B. Incision on the right edge of gallbladder bed. C. Vertical incision on the segment 7 perpendicular to the hepatic hilum. (b) Right hemihepatectomy—a large laparoscopic vascular clamp is introduced through incisions A and C to occlude the right Glissonian pedicle. (c) Right posterior sectionectomy—combining incisions B and C, it is possible to occlude the Glissonian pedicle of segments 6 and 7. (d) Right anterior sectionectomy—combining incisions A and B and using the same maneuver, it is possible to occlude the Glissonian pedicle of segments 5 and 8. (From Machado MA et al. *Am J Surg* 2008;196:e38–42.)

cautery. The vascular clamp is then replaced by the stapler (**Figure 74.2c**). Liver ischemic delineation is checked and if coincident with previous demarcation, the stapler is fired (**Figure 74.2d**). The liver is transected along the marked area. The right hepatic vein is divided with the stapler, completing the procedure (**Figure 74.2f**).⁸

Bi-segmentectomy 5–8

Control of the anterior right Glissonian pedicle is achieved with two small incisions. A clamp is introduced through incisions B and C to control the anterior right main Glissonian pedicle. Ischemic delineation of the right anterior sector (segments 5 and 8) is achieved and is marked along the liver surface with cautery. The vascular clamp is then replaced by the stapler, and the stapler is fired. Liver parenchyma is then transected along the marked area.

Bi-segmentectomy 6–7

After mobilization of the right liver, control of the posterior right pedicle is achieved with two small incisions. A large laparoscopic vascular clamp is introduced through incisions B and C to occlude the posterior right main Glissonian pedicle. Ischemic delineation of the right

posterior sector (segments 6 and 7) is obtained and marked along the liver surface with cautery. The right posterior pedicle is divided. Liver parenchyma is then transected along a marked area.

LEFT LIVER: PATIENT POSITION AND TROCAR PLACEMENT

The patient is placed in a supine position with the surgeon standing between the patient's legs. This technique uses four trocars.

Anatomical landmarks used for laparoscopic Glissonian approach left

In order to reach Glissonian pedicles from the left liver, we use small liver incisions according to specific anatomical landmarks.^{5,7} The left lobe is pulled upward, and the lesser omentum is divided, exposing the Arantius ligament (*ligamentum venosum*). The Arantius ligament is divided. The caudal stump of the ligament is used as a landmark for the left Glissonian pedicle. A small (3 mm) anterior incision is made in front of the hilum, a round ligament is retracted upward exposing the umbilical fissure between segments 3 and 4. Two small incisions are performed on the right and left margins of the round ligament, respectively. Another

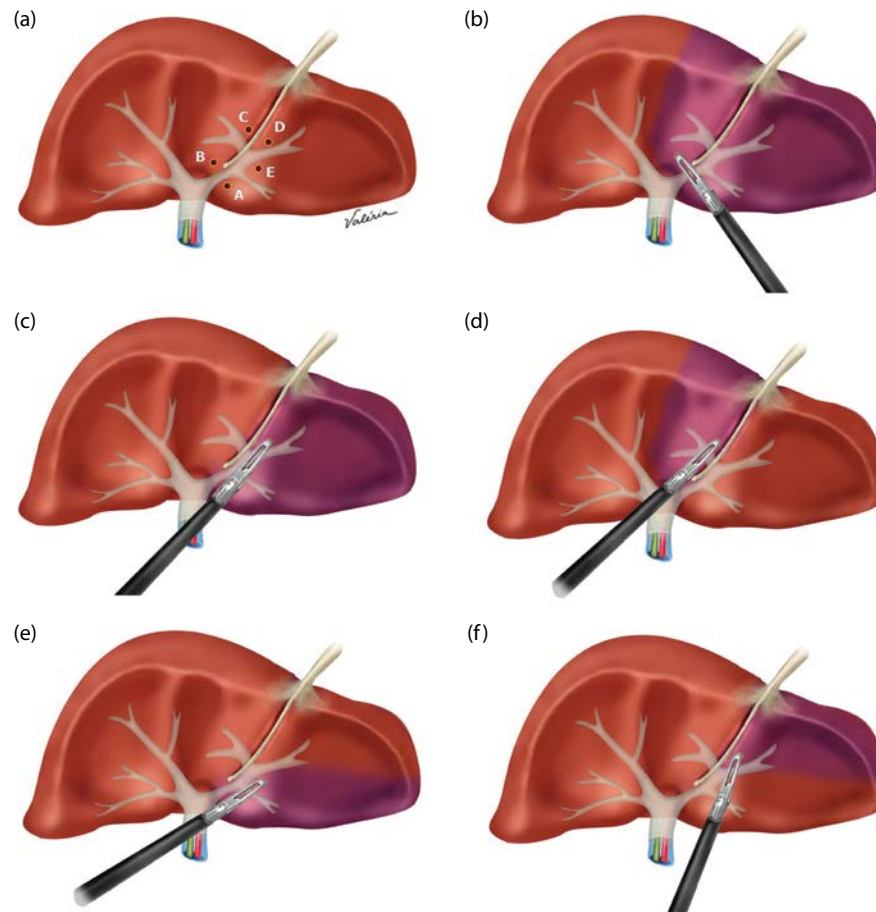


Figure 74.2 Intrahepatic Glissonian access for laparoscopic left liver resections. (a) Landmarks for access of the left liver segments Glissonian pedicles. Site A indicates the caudal stump of the Arantius ligament; B, the anterior incision in front of the hilum; C, the basis of the round ligament, right side; D, the basis of the round ligament, left side; E, midway between sites D and A. (b) Left hemihepatectomy—a large laparoscopic vascular clamp is introduced through incisions A and B to occlude the left Glissonian pedicle. (c) Bisegmentectomy 2–3—combining incisions A and D it is possible to occlude the Glissonian pedicle of segments 2 and 3. (d) Segmentectomy 4—Combining incisions B and C and using the same maneuver, it is possible to occlude the Glissonian pedicle of segment 4. (e) Segmentectomy 2—combining incisions A and E and using the same maneuver, it is possible to occlude the Glissonian pedicle of segment 2. (f) Segmentectomy 3—combining incisions E and D and using the same maneuver, it is possible to occlude the Glissonian pedicle of segment 3. (From Machado MA et al. *Surg Endosc* 2009;23:2615–9.)

small incision can be performed in the midway between incisions A and D allowing individual access to either segment 2 or 3 pedicles, allowing individual resection of segments 2 and 3. The left hepatic vein or the common trunk can be dissected and encircled before liver transection. This maneuver is usually not necessary unless there is proximity of the lesion with hepatic veins.

Left hemihepatectomy (segments 2, 3, and 4)

After mobilization of the left liver, control of the left pedicle is achieved with two small incisions. A clamp is introduced through those incisions to occlude the left main Glissonian pedicle. Ischemic delineation of the left liver (segments 2, 3, and 4) is obtained and is marked along the liver surface with cautery. The

vascular clamp is then replaced by the stapler, and the stapler is fired. Liver parenchyma is transected along the marked area. The left hepatic vein is then divided with the vascular stapler. The middle hepatic vein can be spared in some circumstances when the tumor is away from the common trunk.⁹

Removal of segment 1

Control of the Glissonian pedicle from segment 1 is also achieved with two small incisions. The first incision is made above the caudal stump of the Arantius ligament and the second in the caudate notch. A clamp is introduced through those incisions to occlude the segment 1 Glissonian pedicle. After division of the segment 1 pedicle, the liver is transected along the marked area.

Removal of segment 2

Control of the Glissonian pedicle from segment 2 is achieved with two small incisions. A vascular clamp is introduced through those incisions to occlude the segment 2 Glissonian pedicle. Ischemic delineation of segment 2 is achieved and marked along the liver surface with cautery. The vascular clamp is then replaced by an endoscopic vascular stapling device, and the stapler is fired. The liver is then transected along the marked area. Care must be taken in order not to damage the left hepatic vein branch to segment 3.

Removal of segment 3

Control of the Glissonian pedicle from segment 3 is achieved with two small incisions. A laparoscopic clamp is introduced through those incisions to occlude the segment 3 Glissonian pedicle. The pedicle is divided with the stapler, and the liver is transected. Care must be taken in order not to damage the left hepatic vein branch to segment 2.

Removal of segment 4

Control of the Glissonian pedicle from segment 4 is achieved with two small incisions. A vascular clamp is introduced through those incisions to occlude the segment 4 Glissonian pedicle. The vascular clamp is then replaced by an endoscopic vascular stapling device, and the stapler is fired. The liver is then transected along the marked area.

Bi-segmentectomy 2–3

After mobilization of the left liver, control of the Glissonian pedicles from segments 2 and 3 is achieved with two small incisions. A clamp is introduced through those incisions to occlude segments 2 and 3 Glissonian pedicles. Ischemic delineation of segments 2 and 3 is obtained and is marked along the liver surface with cautery. Once ischemic delineation is coincident with previous demarcation, the stapler is fired. The liver is then transected.

RIGHT AND LEFT LIVER

A combination of left and right intrahepatic Glissonian approaches may be necessary to perform central hepatectomies (mesohepatectomies) or extended left or right hepatectomies (trisectionectomies). There are several possible

combinations, but the essential technical principle is the same as previously described.

Mesohepatectomy (removal of segments 4, 5, and 8)

This technique is used to control the right anterior (segments 5 and 8) and segment 4 Glissonian pedicles. Ischemic delineation of segments 4, 5, and 8 is marked along the surface area with cautery, and the liver substance is transected.¹⁰

Right trisectionectomy

For this operation, previous right portal vein occlusion is usually necessary, depending on future liver remnant volume. This technique uses a combination of pedicle 4 and main right pedicle control. Liver transection is performed toward the main trunk to prevent damage to the left hepatic vein. Falciform ligament is fixed to the abdominal wall in order to prevent the remnant liver from rotating spontaneously into the right subphrenic space and causing left hepatic vein kinking.¹¹

Left trisectionectomy

This technique uses a combination of right anterior pedicle and main left Glissonian control. Ischemic delineation of the left liver (segments 2, 3, and 4) along right anterior segments (segment 5 and 8) is obtained and is marked along the liver surface with cautery. The liver is then transected along the marked area. This technique spares segment 1 Glissonian pedicle.

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Ablative treatment of liver tumors

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INTRODUCTION

Radiofrequency ablation for solid tissues was described over 100 years ago, but only sporadic reports have surfaced until the end of the twentieth century.¹⁻⁴ By then a large variety of techniques for tissue ablation in solid organs have been described, including those based on heat, cold, radiation, chemotherapy, and intralesional injection of agents (**Table 75.1**). But in standard clinical practice today, only three major distinct technologies for the ablation of liver tumor are in use: cryoablation, radiofrequency ablation (RFA), and microwave ablation (MWA). Clearly, MWA and RFA are becoming the most common technologies used in surgical procedures in the United States today, with MWA slowly replacing RFA as the leading ablation modality. The ablation devices based on these two energy sources were developed in the

last two decades of the twentieth century, spurred by the rapid expansion of treatment indications for primary and metastatic liver lesions. In addition, the development of ablation devices for the treatment of liver tumors is inextricably linked to the technological revolution in minimally invasive surgery and image guidance that occurred at the same time. Tissue ablation technology is still undergoing rapid evolution with refinements of current systems and developments of new devices based on energy provided by ultrasound, lasers, and other energy sources and mechanisms.

Radiofrequency and microwave ablation have important differences in their tissue effects that need to be well understood so as to ensure appropriate and successful treatment of liver tumors. Each of these ablation techniques can be applied through an open, laparoscopic, or percutaneous approach, further complicating the clinical decision-making process and patient selection. Patients planning to undergo ablation of liver tumors should therefore be discussed by a multidisciplinary team where both the surgeon and the interventional radiologist understand the fundamental principles of energy application and tissue effects, are well versed in image guidance techniques, and share their clinical decision process with oncologists, diagnostic radiologists, pathologists, and hepatologists.

The chapter also reviews the current clinical application of RFA and MWA in benign and malignant liver disease, indications and patient selection, techniques, and expected results.

Table 75.1 Ablative modalities for hepatic malignancies

Chemical

- EtOH
- Acetic acid
- TACE (Transarterial Chemo Embolization)

Radiation

- Stereotactic radiosurgery

Thermal

- *Cryoablation*
 - Liquid nitrogen
 - Argon
 - NO₂
- *Coagulative*
 - Radiofrequency
 - Microwave
 - Laser
 - HIFU (High Intensity Focused Ultrasound)

PRINCIPLES OF RADIOFREQUENCY ABLATION

RFA is a special application of radiofrequency electrosurgery designed to coagulate large volumes of solid organ tissue. To achieve this goal, the main aspect of RFA technology is to achieve sufficient levels of tissue temperatures to obtain coagulation but avoid higher temperatures causing vaporization or carbonization (greater than 100°C). This

serves the most important and desired tissue effect of RFA: destroying the largest possible volume of tissue. The undesired tissue effects of vaporization and coagulation would be counterproductive as they create tissue zones of very high electrical resistance and therefore hinder propagation of energy away from the active RFA electrode for optimal tissue destruction.

The technological concept of RFA is built on an active electrode placed into the target tissue. Alternating current at radiofrequencies of 375–500 KHz is sent through a closed circuit that connects through the patient with an active electrode and large dispersive electrodes (“grounding pads”) (Figure 75.1). The alternating polarity of the current generated produces rapid oscillation of intracellular ions and proteins (Figure 75.2). This creates friction that is responsible for the rise in tissue temperature, thus creating the desired tissue effect of coagulation necrosis around the active electrode. The optimal tissue effect is observed at temperatures between 60°C and 100°C, at which simultaneous protein coagulation and tissue desiccation occurs. Temperatures below 50°C or above 100°C either do not lead

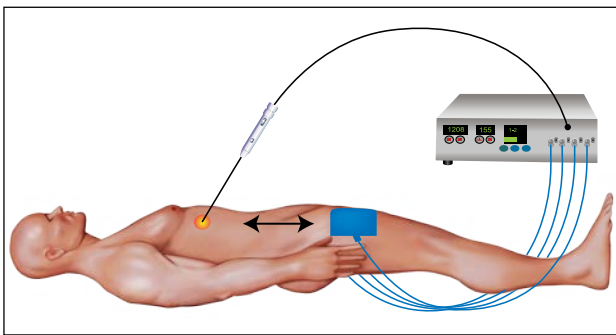


Figure 75.1 Electrical circuit of an RFA system: The patient is part of a closed-loop circuit created by the ESU, the active electrode, and one or more large dispersive electrodes.

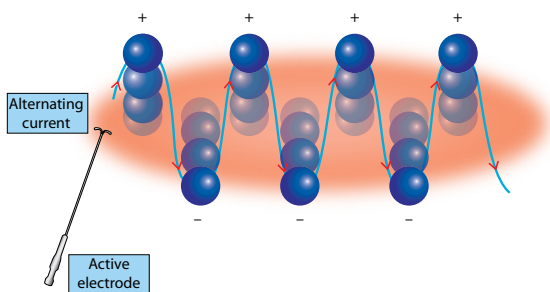


Figure 75.2 Alternating current is applied through the active ablation electrode. An alternating electric field is created and causes agitation of ions, which leads to frictional heat production.

to cell death or create premature and complete tissue desiccation, which acts as an insulator for appropriate propagation of energy and therefore results in inadequate tissue destruction. Target tissue heating, also termed *resistive* of joule heating, occurs at the narrow interface between the active electrode and the target tissue, which represents the area of highest current density. The destruction of a larger ablation zone during FRA is accomplished through conductive heat transfer outward from this narrow interface. The “tissue”-effective distance of this heat transfer determines the size and shape of the ablation zone. The current is controlled and modulated through a complex computer-controlled electrosurgical unit (ESU) (Figure 75.3). A typical RFA of a 3 cm lesion on average will take 15–25 minutes depending on the system used, target tissue properties, and characteristics of the liver parenchyma. Of note, bipolar RFA devices, MWA, and cryotherapy do not require a dispersive electrode. An additional peculiarity of RFA systems is the unusually high power generated by the ESU to achieve maximum volumetric effects in the target tissue. Modern RFA systems generate up to 200 Watts of energy within the electrical circuit. Consequently, the dispersive electrode, which is responsible to disperse this amount of energy onto a large area of skin without creating a thermal effect, needs to be very large. Some systems use more than one dispersive electrode to prevent skin burns during prolonged activation of the system.^{5,6}

It is essential to understand that the previously mentioned intracellular tissue effects driven by ion and protein oscillation only occur within a few millimeters of the active RFA electrode. The final ablation zone is mainly determined by thermal conduction away from this immediate destruction zone around the active electrode, similar to microwave ablation shown in Figures 75.11 and 75.18. This heat conduction process takes time, and it is very important that the deposition of energy immediately around the active electrode through ion and protein oscillation continues during the time it takes to conduct heat into the outer zone of the ablation. This explains why it is critical for a successful RFA to maintain conductivity to radiofrequency current



Figure 75.3 Typical ESU for RFA. Monitoring of impedance and/or temperature at the active electrode is used to adjust energy output.

immediately around the active electrode for as long as possible. Delaying the point where tissues around the active electrode inevitably become completely desiccated or start to vaporize is paramount to obtain the most effective volumetric ablation. Several effects are responsible for an optimal RF ablation: (1) The water content of the targeted tissue determines how long energy deposition around the active electrode through ionic agitation will occur. The higher the initial water content, the longer the tissue will accept energy deposition. The result is a larger ablation zone. Because RFA is a self-limiting process due to eventual desiccation of the target tissue, the initial characteristics of the target tissue, i.e., the water content and ionic content, determine the size of the ablation. This is clinically relevant as, for example, colorectal cancer metastases have little water content compared to neuroendocrine metastases. (2) Inevitably, the tissue resistance or impedance due to the formation of steam or charring will limit the ablation process. The optimal result, i.e., obtaining the largest possible ablation zone with RFA, is therefore accomplished by controlling energy deposition around the active electrode to prevent as long as possible the inevitable occurrence of high resistance. This is achieved by the ESU, which regulates the amount of energy in the circuit according to measured tissue temperature and/or tissue resistance at the active electrode, depending on which system, algorithm, and active electrode design is used, and by the design of the active electrode that might include cooling of the electrode tip to reduce excessive heat buildup immediately around the active electrode (**Figures 75.3 and 75.4**). Most RFA ESUs keep the output voltage at a low 60 volts, a level that is below the threshold that can cause sparks and

charring at the active electrode tip. The similarity to trying to cook meat well done on a barbecue comes to mind: rapid heating causes carbonization of the outside surface and prevents the raw center from cooking.

INTRAOPERATIVE ULTRASOUND GUIDANCE FOR RADIOFREQUENCY ABLATION AND MICROWAVE ABLATION

Optimal operative results for both RFA and MWA depend in large part on accurate intraoperative placement of the active electrode. In minimally invasive approaches and with the exception of superficially visible lesions, this requires the use of intraoperative image guidance with ultrasound. In open surgical approaches, palpable lesions, even if they are not visible on the surface, can usually be accurately treated without the use of image guidance.^{34,35,56}

Ultrasound (US) guidance technique needs to be acquired by any surgeon wanting to perform liver ablations. High-frequency (7–10 Mhz) flat transducers are optimal, as they provide the least “distortion.” Smaller “curved” probe designs allow better visualization of very deep-seated lesions but introduce some element of “distortion” of the image. Both types of US probes allow placement of the US view parallel to the long axis of the active electrode, which facilitates its guidance to the target. In addition, rigid ultrasound probes facilitate further active electrode and probe placement, as one can more easily maintain the viewing angle during placement. Flexible US probes tend to “wander” during manipulation and can add complexity to the maneuver of electrode and probe placement. Manufacturers do provide steel sleeves to convert flexible US probes to rigid probes. These can be very helpful during placement in posterior liver segments that are out of view by the laparoscope. One achieves best results initially by placing the long axis of the US probe parallel to the intended line of introduction and long axis of the active electrode while keeping the target lesion in the US view at all times. Some laparoscopic US probes facilitate this approach by providing a metal guide for the electrode placement that keeps the electrode inside the US viewing field at all times. Open surgical ablation procedures allow the “easy” parallel placement of US probe and electrode for nearly any location within the liver tissue, as extensive liver mobilization can be performed and sufficient room can be created for US probe placement even in difficult posterior liver lesions close to the hepatic vein confluence (**Video 75.1**). **Video 75.3** demonstrates the parallel US guidance of an MWA probe (**Video 75.3**). The flexibility and maneuverability of the US probe are sometimes reduced when the minimally invasive approach is used and may require departure from the parallel placement of US field of view and active ablation electrode. In these circumstances, an angle (45° or 90°) is present between the long axis of the US view and the active electrode (**Videos 75.2 and 75.4**). This makes placement more difficult as the surgeon can only see a small portion of the active electrode within the US view. Accurate placement of

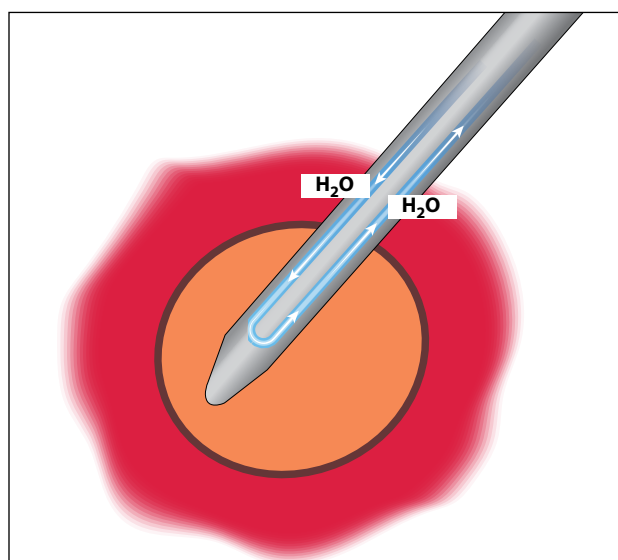


Figure 75.4 Active RFA electrodes of different proprietary design. The design tries to achieve the greatest energy deposition while reducing rapid heating that could cause unwanted charring or vaporization of tissue. Active electrode cooling shown.

the active ablation electrode in all possible liver segments by the minimally invasive approach therefore requires a certain learning curve and training. **Video 75.1** shows the accurate placement of an active RFA probe during an open liver ablation procedure and demonstrates the “parallel” placement technique. **Video 75.3** demonstrates the parallel US-guided placement of a MWA probe for liver ablation. **Videos 75.2 and 75.4** show laparoscopic US-guided placements of an MWA probe in 45° and 90° angles.

If more than one target lesion is present and because recently ablated tissue contains microbubbles of air and steam that obscure the view with US, it is important to adhere to a specific sequence of ablation starting with the deepest parenchymal lesion first. Otherwise the superficially ablated lesions may make it impossible to accurately assess deeper lesions for accurate electrode or probe placement. This principle also applies if one lesion is ablated using several superimposed ablation zones (**Figure 75.5 and Video 75.5**).

Videos 75.1 and 75.2 demonstrate correct placement of the active electrode tip in relation to the target lesion for the specific electrode used in an open ablation procedure. Each proprietary design and ablation device, be it RAF or MWA, has their specific instructions where to place the tip of the electrode or probe in relation to the target lesion for optimal results, and the surgeon needs to be knowledgeable about the specific instructions of the ablation system he or she uses.

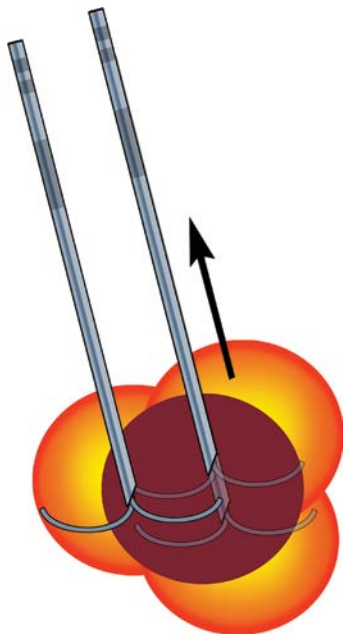


Figure 75.5 Placement of multiple electrodes to ablate larger liver lesions. To maintain good visibility of the original target lesion, ablation is started the furthest away from the US probe, usually with the most “distal” aspect of the target lesion. (Courtesy of Dr. Steve Curley.)

OPERATIVE RADIOFREQUENCY ABLATION TECHNIQUE

Placement of the active electrode is a crucial step to assure successful ablation. Regardless of surgical approach, in most instances of liver ablation, image guidance by intraoperative US should be used (**Video 75.1**). This requires the surgeon to be facile with intraoperative US technique as previously described. Each proprietary electrode design comes with a different “optimal” placement of the active RFA electrode in relation to the targeted lesion.⁷ Larger targets may require placement of more than one electrode, either sequentially or at the same time. This is dictated by the ability of the ESU to drive several active electrodes at once.

If the goal of RFA is complete destruction of the liver lesion with a margin of noninvolved tissue, then factors determining the size of ablation need to be known by the surgeon. As discussed, the ablation size is established by both the inherent characteristics of the target lesion and the tissue qualities of the surrounding liver. The most important determinant of ablation size is the electrical and thermal conductivity of the targeted tissues. Conductivity is inversely related to tissue resistance or impedance and directly correlated to the tissue water content. For the RF ablations of liver tumors, the following principles apply and need to be taken into account by the surgeon: (1) *The length of ablation*. Heat conduction through the target and liver tissue occurs slowly. As this effect is responsible for most of the ablation zone, the length of an ablation needs to be timed to allow effective heating of all target tissues. The proprietary algorithm of each RFA system will provide exact guidance on the timing of a liver ablation according to the size of the targeted lesion. The surgeon does need to understand the qualities of the liver tissue and needs to adjust timing accordingly. Fatty livers and cirrhotic liver exhibit different water contents than normal liver tissue. In general, high target lesion water content and low surrounding liver water content are conducive for an improved and successful ablation. Therefore, larger lesions can be successfully ablated in this circumstance compared to a situation of a low water content in a target lesion and high water content in surrounding liver. Prime examples are hepatocellular carcinoma in cirrhotic livers (high target versus low liver water content) and colorectal cancer metastases in normal or fatty livers (low target versus high surrounding liver water content). It is therefore important to be mindful of the tissue characteristics during an ablation and adjust the ablation length accordingly. The surgeon can use the Pringle maneuver to decrease the thermal conductivity of the surrounding liver tissue to mitigate differences in conductivity between target lesion and surrounding parenchyma and increase the ablation zone.⁸ (2) *Uneven deposition of energy and thermal conductivity*. Due to uneven thermal conductivity and water content in any human tissue energy deposition during ablation is always uneven. The tissue effect is therefore delivered at varying speeds to the entire lesion. The surgeon must take this into account



and allow ample time for a complete ablation. Furthermore most target lesions do not exhibit an ideal spherical shape (**Figure 75.6**). Neither does a typical ideal ablation zone as the electrical field around an active RFA electrode is never completely spherical. It is important for the surgeon to understand the typical shape of a particular RFA active electrode and adjust the ablation procedure accordingly. At the same time the surgeon has to consider the three-dimensional shape of the target lesion and adjust the placement of the active electrode to maximize overlap of expected ablation zone and target lesion shape.

Multiple ablations with one electrode or the use of multiple electrodes may be necessary to achieve optimal results. Because previously ablated tissue may obscure the US view, it is important to start ablation of the most “distal” aspect of the target lesion first (**Figure 75.5**).

In addition to target shape, electrode configuration, and tissue characteristics, the presence of a large vessel can interfere with the even distribution of energy deposition during RFA and create “distorted” ablation zones.^{20-22,33} A large blood vessel close to a RFA, for example, can create both a “heat sink,” as the rapid high-volume blood flow removes heat at a higher rate than it is deposited by the ablation, and because RFA tissue effect is based on the flow of electrical current, an “electric sink,” whereby the current preferentially takes the path of least resistance through large blood vessels or bile ducts (**Figure 75.7**). This is likely one of the most important factors leading to incomplete or uneven ablation zones and failure of RFA. A surgeon’s knowledge of liver anatomy is therefore critical. One has to be cognizant of the presence of large veins or arteries during RFA and adjust placement of active electrodes accordingly. **Table 75.2** lists the potential complications of RFA.

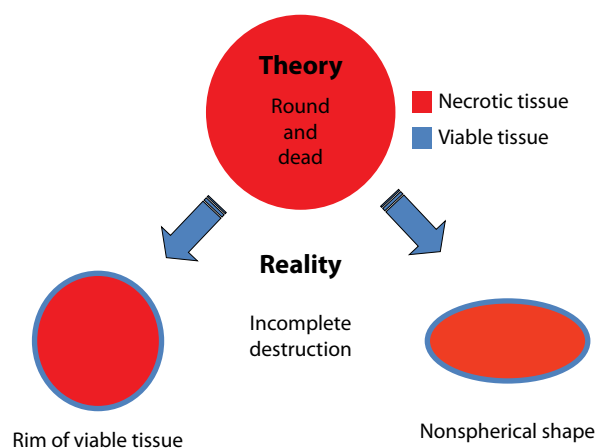


Figure 75.6 A spherical RF ablation occurs only in theory. Ablation zone shape is dictated by many factors and is always irregular. For the surgeon, this means that the threat of an incomplete ablation is always present and needs to be considered during any ablation procedure.

Ablation close to vessels

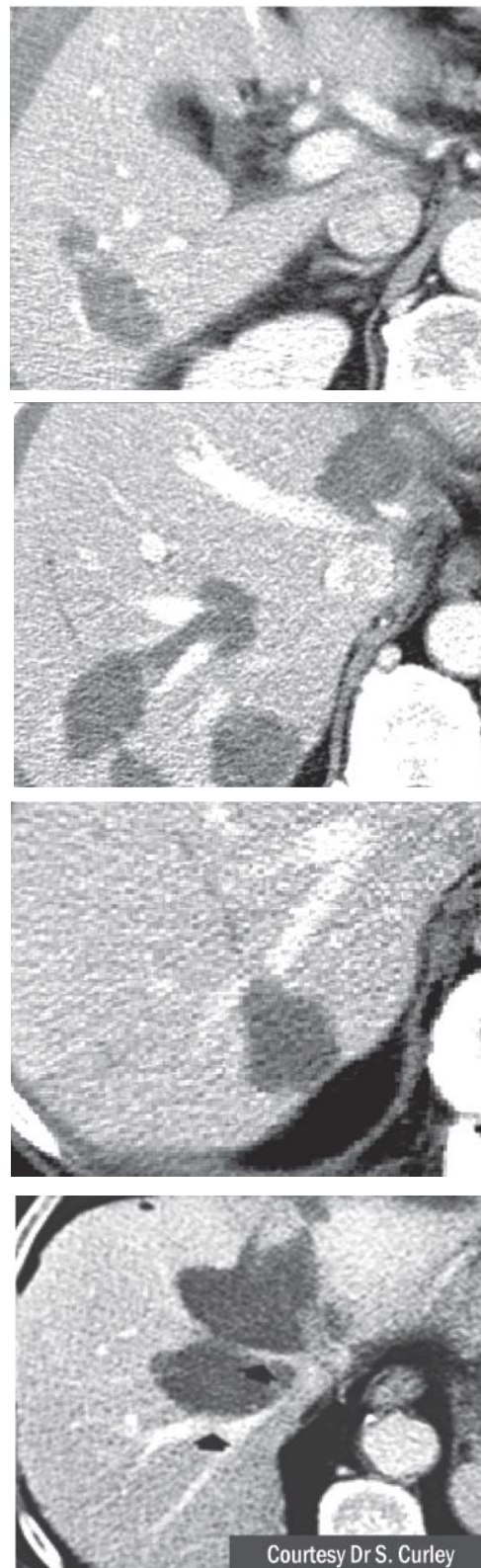


Figure 75.7 The effect produced by a large vessel adjacent to an ablation zone during RFA. Both “heat sink” with distortion of the heat conduction zone as well as “electrical sink” with distortion of the primary ablation zone occurs.

Table 75.2 Examples of potential adverse events from RFA and how to prevent them

Injury	How to prevent	Potentially life threatening
Hyperthermia	Monitor intraoperative core temperature	No
Skin burns	Correctly place dispersive electrode	No
Vascular injury	Avoid excessive ablation close to large vessels	Yes
Biliary injury	Avoid ablation close to liver hilum	Yes
Organ injury	Create space between liver surface and adjacent organ	Yes
Diaphragmatic injury	Create space between liver surface and diaphragm	Yes
Liver abscess	Do not ablate with biliary obstruction or cholangitis	No
Tumor rupture/seeding	Avoid ablation of large surface lesions	No

PRINCIPLES OF MICROWAVE ABLATION

Similar to RFA, MWA is based on radiofrequency current but uses it at much higher frequencies (shorter wavelength) of 900 MHz and higher. The energy used is not a current but rather an electromagnetic (EM) wave. This completely changes energy transport and heat generation within targeted tissue. The differences in physical properties of MWA compared to RFA need to be well understood by the treating surgeon.^{8–11} The main principle of MWA lies in the delivery of energy at microwave frequencies (915 MHz–9.2 GHz). This translates into a wavelength of only a few centimeters compared to several meters for RFA. The large difference in wavelength is the main reason for the observed differences in tissue effects seen with MWA compared to RFA. Because of its large wavelength, RFA energy is unable to travel the short distance from the ESU to the active electrode in the form of an EM wave. Most of the energy moves as alternating current, and the current flows from the electrode tip through the tissues, requiring a large dispersive electrode. The wavelength used in MWA is short enough to transport most of the energy as an EM wave down the shaft of the active electrode to the “radiating tip” or antenna where it is “broadcast” outward to form a spherically shaped EM near-field in the target tissue (**Figure 75.8**). The lack of current flow obviates the need for dispersive electrodes. The MW near-field represents the unique aspect of MWA, as direct heating is delivered to tissue much farther away from the immediate contact interface between active “electrode” and target tissue compared to RFA.¹³ The EM near-field at the tip of the active MW antenna rapidly changes polarity at the MW frequency (10^9 times per second) and thus heats the target tissue by a “dielectric heating” effect. This effect describes the generation of heat that is produced by the rapid rotation of dipole molecules (mainly water) near the frequency of the changes in EM field polarity (**Figure 75.9**). Because the changes in polarity (oscillations) at MW frequency are so high, the rotation of the dipole molecules lags behind and produces resistive heating. This MW near-field creates an intense and uniform direct “active” heating zone within the target tissues. As with RFA but to a lesser degree the ablation zone is further extended outward by “passive” conventional heat conduction (**Figure 75.10**). The tissue effects of the MW near-field and heat conductivity

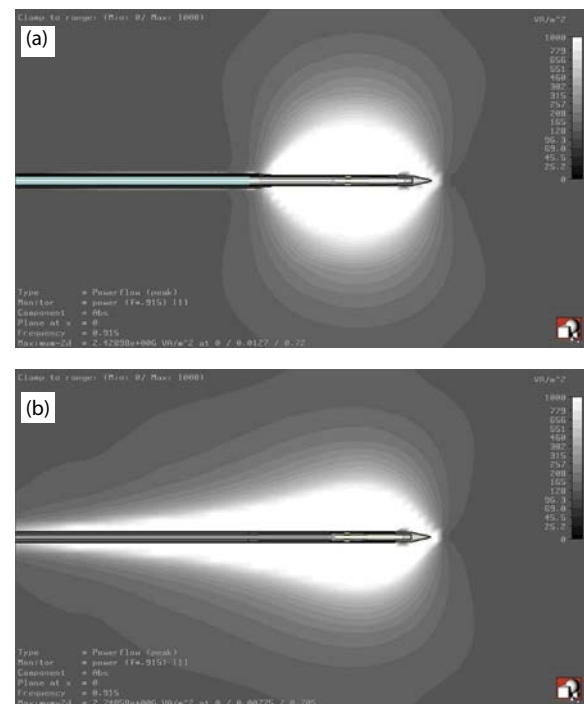


Figure 75.8 Visualization of a typical electromagnetic field produced by the MWA probe. The spherical field is obtained by using a choke (metal ring) at the beginning of the “active” probe tip. Without the choke, the ablation zone is less spherical.

depend on the intrinsic qualities of the target tissue and the frequency of the MW energy applied. Different target tissues exhibit different abilities to respond to dielectric heat production. This difference in tissue characteristic is termed the *dielectric constant* or *permittivity* (**Figures 75.9 and 75.11**).

Currently available MW systems for liver ablation use 915 MHz and 2.45 GHz frequencies. The generators for MWA are a solid-state system based on transistor technology, which has some advantages over the magnetron technology of regular microwave ovens.¹² It allows simple controls for energy output based on wattage and ablation time settings. Delivered energy varies between 30 and 180 Watts with ablation times ranging from 4 to 10 minutes depending on system frequency

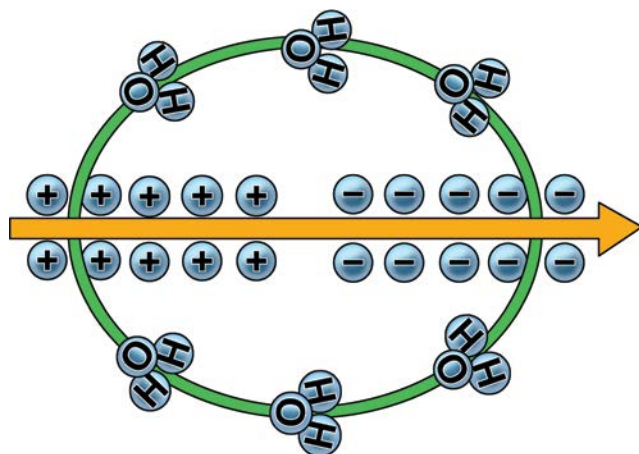


Figure 75.9 Dielectric heating of water molecules through excitation by the EM field polarity changes at MW frequency.

(a) Active and passive zone components of a thermal ablation zone (b) Passive zone distortion by anatomical factors

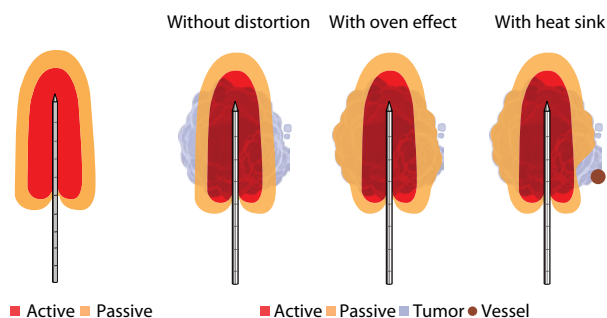


Figure 75.10 (a) The active and passive thermal zones with MWA. (b) When the target lesion size exceeds the primary ablation zone (near-field in MWA and zone of current flow in RFA), the size of the final ablation zone is determined by the heat conductivity of the target tissue. Here is one example where heat conductivity of the target tissue exceeds that of the surrounding liver and leads to ablation of the target tissue that is in continuity with the primary ablation zone. Note that there are still areas of the target tissue that are not affected by the ablation. Ablation modalities with larger primary ablation zones such as MWA have therefore a possible advantage.

and design. As with RFA systems, each commercially available MWA system has proprietary algorithms, specific antenna designs, and placement recommendations that need to be carefully observed to obtain optimal results.

It is critical for the surgeon to understand the fundamental principles of antenna design in MWA, as this determines the use in minimally invasive versus open surgery and the shape of the MW near-field, the aspect of the energy delivery that is most responsible for the shape and size of the ablation zone. The handpiece used in MWA is essentially an EM conductor with an active tip (Figure 75.12). The tip

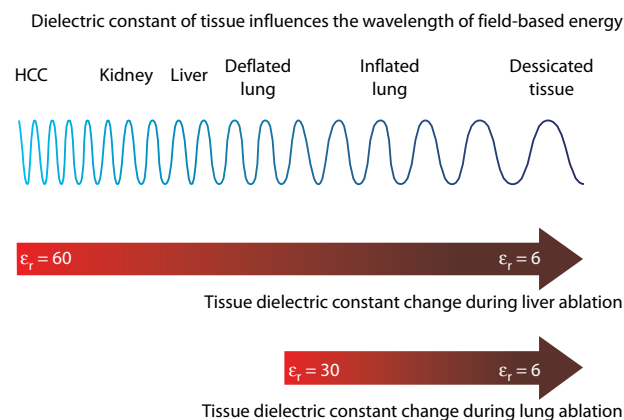


Figure 75.11 Influence of tissue characteristics on tissue effect by the MWA near-field EM energy. Modern proprietary MWA systems adjust the EM wavelength accordingly to optimize the ablation zone.

becomes active by removing or folding back the outer conductor, allowing the EM wave to radiate into the target tissue and form the near-field described. The specific design of the antenna determines the size and shape of the ablation zone, and innovations in antenna design have constantly improved the symmetrical shape and reliability of the ablation zone in MWA.¹³ These improvements are achieved by minimizing energy loss from impedance mismatch and reflected energy through the use of antenna tip cooling, use of a metallic ring around the distal handpiece shaft that limits energy loss from reflection, and wavelength control to adjust to changes in the dielectric constant of the tissue during the ablation process due to progressive water content loss and desiccation. Figure 75.13 demonstrate schematically how some of these technologies improve the results of MWA. Each proprietary design has different properties in this regard, and they undergo extensive preclinical testing to find optimal power and duration settings for a given tissue.^{14,15} Surgeons using ablation systems should also be well aware that claims of ablation sizes obtained *ex vivo* by proprietary systems may differ substantially from *in vivo* results and may differ also if obtained in animals under “standard” conditions versus human beings in clinical practice.

Handpieces used in minimally invasive surgery are designed for transcutaneous placement with thinner and longer shafts, and built-in cooling to prevent skin burns secondary to shaft heating.¹⁶ Handpieces used in open surgical MWA procedures do not require the added cooling circuit.

GENERAL MICROWAVE ABLATION TECHNIQUE

As with RFA ablation of liver lesions with MWA follows the same basic technique: optimal localization of the target lesion with image guidance, adherence to the MWA antenna placement into the target lesion according to proprietary algorithm, and protection of intrahepatic and perihepatic structures

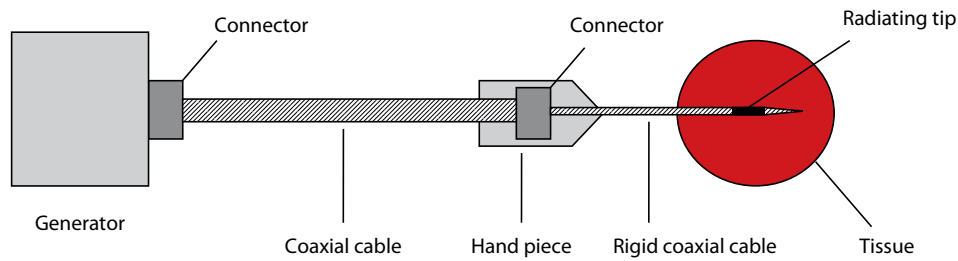


Figure 75.12 A microwave ablation system. The microwave generator will generate microwaves at a set frequency, which are directed down the transmission line to the handpiece, which has a connector and a second rigid transmission line ending in the microwave antenna, also called the radiating tip, which is embedded in the target tissue.

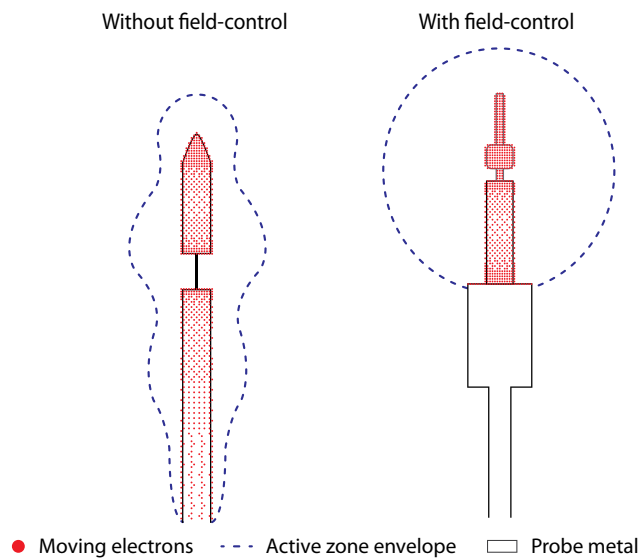


Figure 75.13 Modification of MWA probe design and placement of chokes (metal rings) around the probe influence the shape of the near-field (active zone). Improvements in proprietary designs use these techniques to advance the reliability and spherical shape of MWA zones in clinical practice.

(**Video 75.4**). Practically any target lesion within the liver can be accessed through minimally invasive technique for MWA but may require adequate mobilization and traction of the liver to be able to reach the target lesion and avoid injuring surrounding organs and structures. Placement of a hand-port and use of surgical sponges to keep tissues separated may be necessary. It is important not to place one's hand or the ultrasound probe too close to the near-field of the ablation zone for a prolonged time during MWA procedures. When ablating liver lesions, the surgeon should be facile in recognizing and addressing injuries to major hepatic structures such as the portal vein branches, hepatic veins, and bile ducts.

Advanced skills in intraoperative ultrasound are essential. The targeting of a specific liver lesion may be impossible without excellent three-dimensional orientation of the US probe in relation to the target. This will allow the surgeon to

choose the correct angle for the MWA probe insertion into the liver parenchyma. Once inserted, changing the direction of MWA probes is difficult, as these probes are rigid and hollow and therefore easily damaged compared to RFA electrodes. Attempts to change direction during insertion can also lead to serious vascular or biliary injury. This is particularly difficult to accomplish when using minimally invasive approaches and the MWA probe has to be placed transcutaneously at the correct angle, then inserted into the liver at the correct angle, and hit the target lesion at the right spatial orientation to provide optimal energy deposition. The use of flexible laparoscopic US probes can further complicate this maneuver, as an additional changing three-dimensional plane is added. Therefore, it is advisable to use rigid probes instead or use a rigid sleeve over the flexible probe. The easiest image-guiding plane results from a parallel orientation (in-plane) of both the US probe and the MWA probe. This will show the MWA probe as a long bright line in the US image. However, at times the surgeons will be forced to use both probes at an angle (out of plane), and the shaft of the MWA probe will only show as a small bright "spot" on the US image. One needs to be facile in using both approaches. To facilitate US recognition of the MWA probe tip or antenna, an echo-intense marker is placed at the point in the antenna where the MW energy is emitted. Usually this echo-intense point should be placed in the center of the target lesion.

The rigid shaft of the MWA handpiece can become very hot during an ablation procedure. This is of particular concern when multiple transcutaneous probes are placed in an "array" in minimally invasive procedures.¹⁶ If the probes are less than 1.5 cm apart, full-thickness thermal injuries to the abdominal wall can occur (**Figure 75.19**). The heating of the shaft is caused by reflected EM energy, and this phenomenon is amplified when two probes are placed close together. Plastic spacers are provided by some manufacturers to prevent this problem. During any MWA a minimum distance of 3 cm between the probe and the abdominal wall should be maintained.¹⁶

In MWA the final size and shape of the ablation zone are determined by several factors that are different from RFA. Electromagnetic energy is dependent on wavelength with higher frequency and shorter wavelength producing less tissue penetration. The design of the antenna, the placement

of chokes, and the dielectric constant or permittivity of the tissues targeted all contribute to a specific shape and size of the ablation zone. These factors are usually not controlled by the surgeon. However, most MWA systems allow the surgeon to change the power setting (Watts) and the duration of a MWA. Higher wattage and longer duration will increase the temperature in the near-field and therefore increase passive heat conduction beyond the near-field, which will result in a larger ablation zone. Therefore, the shape and size of a MWA can be manipulated by choosing an appropriate probe (Figures 75.13 and 75.14), duration, and wattage. A proprietary system provides guidelines in duration and wattage to obtain predetermined ablation size for specific tissue. However, these guidelines are only approximations and to assure adequate ablation sizes.

Following any thermal ablation of liver tissue, a zone of coagulation necrosis is created that will take months to resolve and is therefore visible on follow-up imaging. Because the ablation zone necrosis is susceptible to secondary infection, postablation liver abscess formation can occur and may require percutaneous intervention. This rare complication can cause significant problems and require readmission. It is therefore advisable to use perioperative antibiotic prophylaxis in all liver ablation procedures. Prolonged use of postablation antibiotic coverage may be considered if the ablation was done close to biliary radicals. Postablation imaging will show a fluid collection, sometimes with an air-fluid level. Those routine findings are of no concern, and the clinical course with imaging can usually differentiate this well from a postablation liver abscess (Figure 75.15).

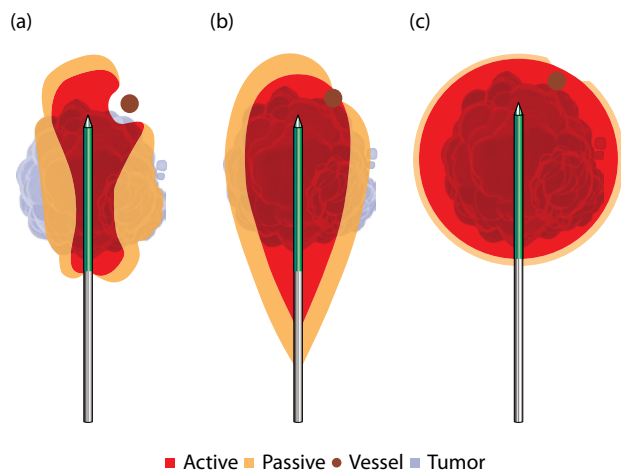


Figure 75.14 (a–c) Comparison of theoretical ablation zones with (a) current-based system (RFA), (b) MWA with “standard” probe design, and (c) MWA with complex probe design. The schema does overexpress the differences seen in clinical practice for illustration. In RFA (a) both the active and passive ablation zone is distorted by a larger vessel acting as a “heat sink.” The effect is less with MWA as long as the vessels lie completely within the active zone or near-field (band c). Special probe designs for MWA are supposed to improve a reproducible and predictable (spherical) ablation zone.

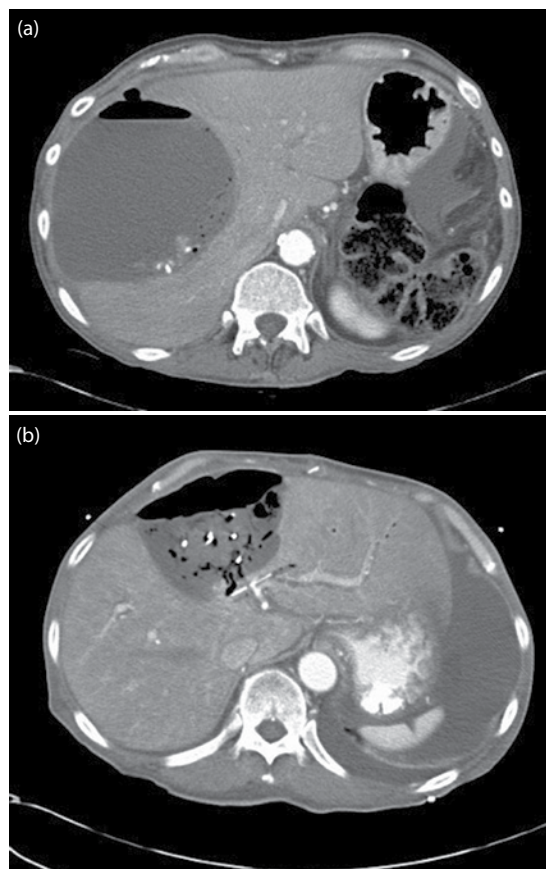


Figure 75.15 Postablation intrahepatic fluid collection versus intrahepatic abscess. (a) Postablation CT showing intrahepatic fluid collection with air-fluid level without infection that resolves without intervention. (b) Postablation CT showing an intrahepatic abscess with clinical and radiographic signs of infection requiring percutaneous intervention.

PRINCIPLES OF CLINICAL APPLICATION OF LIVER TUMOR ABLATION WITH RADIO-FREQUENCY ABLATION AND MICROWAVE ABLATION

The clinical goal of ablation for liver tumors is foremost the complete destruction of the target lesion with an appropriate margin to eradicate the lesion and minimize local recurrence. The difficulty with all ablation modalities resides in the impossibility to exactly predict and control the amount of tissue that is ablated. Compared to surgical resection, this can lead to (1) a higher rate incomplete “destruction” of the target lesion itself, (2) an inadequate margin with increased risk of recurrence, and (3) the added risk of unintended injury to structures within the liver itself, for example, biliary structures, thrombosis of larger vessels, or adjacent to the liver, for example, hollow viscous or diaphragmatic injuries. The rate of inadequate ablations also depends on the type of approach used. In general, percutaneous approaches carry a higher recurrence rate compared to surgical open or laparoscopic

ablations.^{17,18} For the best results, it is important for the surgeon to be familiar with the specific proprietary algorithm for the ablation system used. These algorithms can vary significantly from manufacturer to manufacturer with different anatomic placement of the active electrode in relationship to the lesion, different ablation times, and expected shape and size of the ablation zone. The targeted ablation zone should provide at least a 1 cm margin of uninvolved liver surrounding the target lesion. This may require several staggered ablations or the use of multiple active electrodes at once (Figure 75.5).

Initial series of ablation done with RFA have shown a significant rate of local recurrence with reports as high as 28% for liver tumors.¹⁸ Clinical indications for ablation of liver tumors depend to a large extent on palliative versus curative intent, however, because of the large recurrence rates seen in earlier series that included larger lesions. For curative intent, the indications are relatively narrow: (1) Always resect if resection is technically feasible or patient is a good surgical candidate. (2) If ablation is used either because of concerns due to patient health or because of technical considerations—for example, threat of inadequate residual liver volume or difficult location of lesion—ablation should be used only in lesions around 3 cm or less. Indications for “palliative” intent mainly include pain, benign lesions with risk of bleeding complications, bridge to transplant, and control of tumor burden.¹⁹

It is important to realize that local recurrence after ablation leads to successful salvage only in about half the cases, and that more than one mechanism of recurrence exists. The reasons for local recurrences after ablation are poorly understood but include failure to adequately destroy the lesion due to incomplete ablation, the “heat sink” phenomenon, and possibly local dissemination of viable tumor cells during the ablation procedure due to increase tissue/steam pressure (Figures 75.10 and 75.14). The differences between RFA and MWA are marginal but important. Of note, cryosurgery, which has come out of favor due to reported serious coagulation-related complications and cumbersome technique, has the advantage over RFA and MWA that the ensuing “iceball” is very well seen on US and provides better delineating of the ablation zone than any of the other ablation techniques. The extent of the ablation zone created by both RFA and MWA is more difficult to image and therefore to control. Because of the added potential of heat sink effects distorting the expected ablation zone, RF ablations are the most difficult to predict and demand the closest attention to technique in order to achieve complete ablations of liver lesions. Conversely, the lack of heat sink effects inherent to the MWA technology can lead to an increased risk-unintended collateral damage to bile or vascular structures within the liver and injury to adjacent organs. Comparison of RFA and MWA technologies reveals a trade-off in predictability of shape and preciseness of the interface between ablated and nonablated tissue versus its disregard for tissue interfaces for MWA and a certain unpredictability of lesion shape and size versus relative safety against injury of large vessels or adjacent organs for RFA. The heat sink effect seen with RFA can be used as an advantage close to large vessels,

as it is very difficult to inflict damage or create thrombosis even with the active RFA electrode placed in very close proximity to these vessels. This can be important in situations where lack of sufficient liver parenchyma and resection of lesions very close to large veins or portal branches may increase the risk for liver failure, especially redo operations after major resections. In such scenarios, ablation may provide an advantage, and an experienced surgeon may successfully use RFA with placement of active electrodes very close to large vessels as demonstrated in Figure 75.7.

Serious life-threatening complications of both RFA and MWA are rare but do occur. Most are manageable with interventional techniques; some such as diaphragmatic or hollow viscous injuries may need operative repair. Mortality is exceedingly rare (1% or less). The rate of these complications is less than 5% and may depend on the approach used. In general, an operative approach, laparoscopic or open, compared to a percutaneous approach allows better control of adjacent organ involvement by separating the liver from these structures. Active electrode placement accuracy is also superior during surgical ablation compared to percutaneous techniques.^{9,10} Examples of injury to liver structures and adjacent in RFA and MWA are shown in Figures 75.16 through 75.18. The potential complications and adverse events from MWA are listed in Table 75.3.

COMPARISON OF MICROWAVE ABLATION AND RADIOFREQUENCY ABLATION

Because of differences in physical properties and tissue effects (Table 75.4), both MWA and RFA are deemed to have certain advantages when compared to each other. These advantages are clearly seen in experimental settings but are less obvious in the clinical setting. The main principle difference between RFA and MWA can be attributed to the fact that RFA is very susceptible to the “heat sink” phenomenon, whereas MWA is almost not affected by it.²⁶ This has both theoretical advantages and disadvantages for both modalities.

Because the energy deposited by the EM magnetic near-field in MWA is minimally affected by current flow or heat sinks, and the majority of the ablation volume in MWA is determined by the direct deposition of energy through the near-field rather than through conventional heat conductivity, MWA ablation volumes and shapes are more predictable and reproducible compared to RFA. This is particularly true for the most recent MWA systems that include sophisticated technologies to assure a reproducible spherical ablation zone of a certain predictable size. This has very important implications, as the achievement of a preplanned ablation zone is one of the most desired but at the same time unpredictable goals of any liver ablation. However, the nondiscriminatory tissue effect of the EM field in MWA and its higher temperature of up to 150°C compared to the range of 60°C–100°C during RFA create a higher risk of unintended thrombosis of larger vessels with MWA. In contrast, the heat

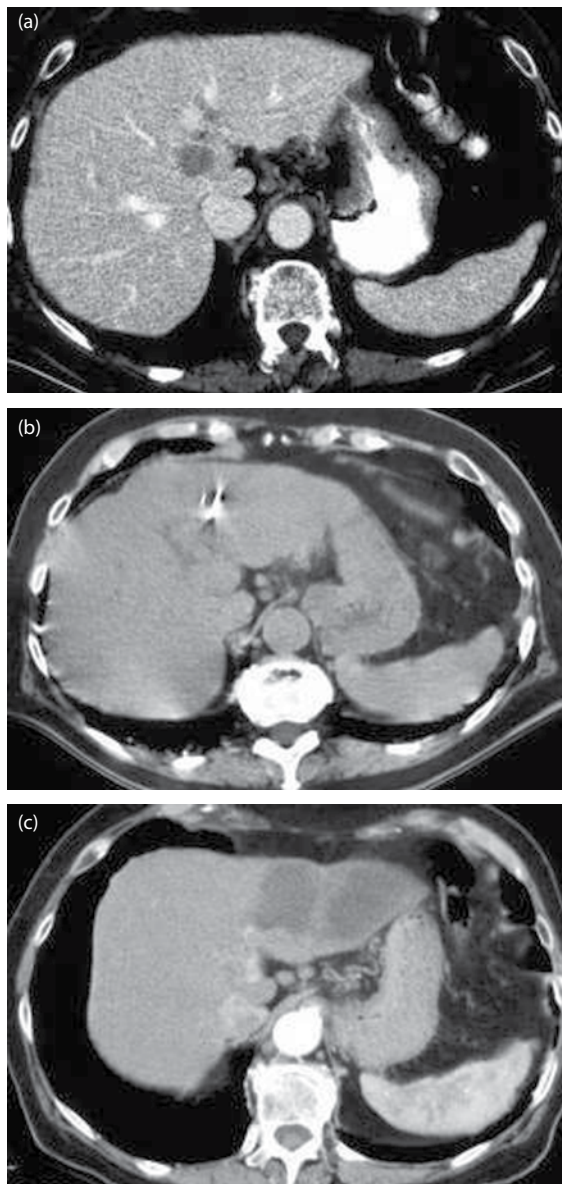


Figure 75.16 Devascularization injury from MWA close to portal pedicle of liver segments II/III. (a) Preablation CT with caudate lobe lesion. (b) MWA of the lesion located near the left portal pedicle. (c) Postablation image showing necrosis of segments II and III. (With kind permission from Springer Science+Business Media: *The SAGES Manual on the Fundamental Use of Surgical Energy [FUSE]*.)

sink effect in RFA can be used to “protect” from injury to large hepatic vessels and facilitate ablation of target lesions located very close to these structures, as shown in [Figure 75.7](#). This requires some experience as the RFA probe needs to be placed close to the vessel and the ablation carried long enough to ablate the target lesion completely, despite the presence of a heat sink. In these special circumstances, RFA may even have an advantage over resection as it may allow preservation of essential hepatic veins to maintain sufficient functional liver capacity. Although similar results can be obtained in experienced hands with MWA, there is a higher

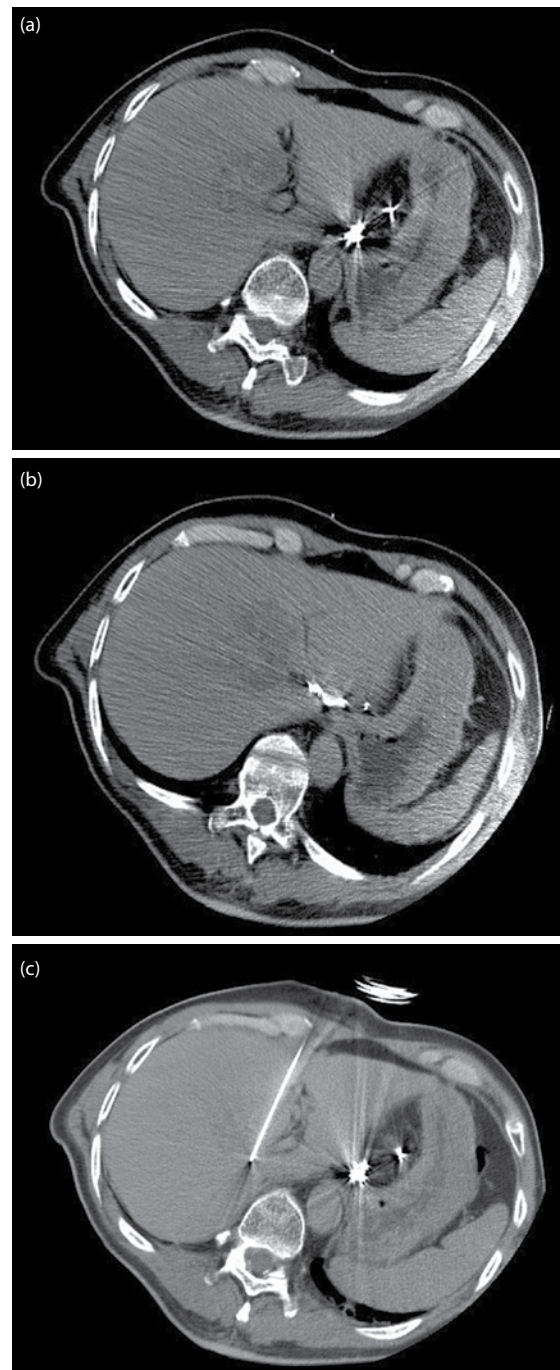


Figure 75.17 MWA close to the main portal confluence: (a) The target lesion is shown close to the main portal triad. (b) MWA probe in the target lesion during ablation. (c) Postablation images demonstrating large intrahepatic bilomas requiring percutaneous drainage. (With kind permission from Springer Science+Business Media: *The SAGES Manual on the Fundamental Use of Surgical Energy [FUSE]*.)

risk of unintended thrombosis of adjacent large hepatic vessels, postprocedure hemolysis, and injury to portal structures with potential serious complications ([Figures 75.16 through 75.18](#)).

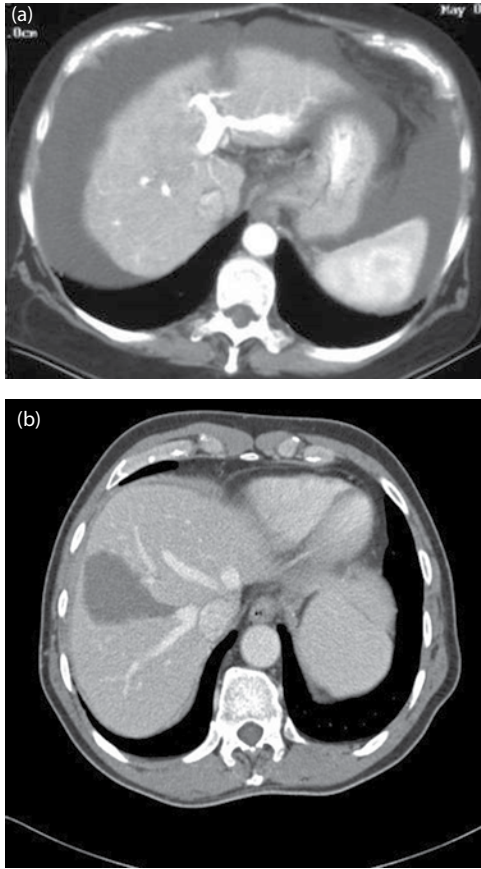


Figure 75.18 Unintended vascular injury from MWA. (a) Porto-arterial fistula formation after MWA. (b) Right hepatic vein thrombosis after MWA. (With kind permission from Springer Science+Business Media: *The SAGES Manual on the Fundamental Use of Surgical Energy [FUSE]*.)

This difference rooted in the MW near-field disrespect for tissue boundaries has additional implications, as the field's energy will also reach across air. In RFA, protection of organ and tissue adjacent to liver is simply obtained by separating both and creating a layer of air to achieve complete insulation from RFA current. When performing MWA, creating an air gap will only protect from conductive heat transfer, not from the energy deposition by the near-field. The surgeon has to create a distance between the MWA target zone and adjacent structures he or she wants to protect from

injury by at least the size of the microwave near-field. This may not be possible during very superficial liver ablations in the minimally invasive setting and may limit the application of MWA in certain circumstances.

In liver ablation, it is not uncommon that several target lesions need to be addressed in one operative procedure. Length of ablation time therefore becomes an important aspect for the surgeon. Both MWA and RFA differ significantly in this respect. In general, the length of a standard ablation is twice as long for RFA compared to MWA. It may take 10–20 minutes to ablate a 3 cm liver lesion with RFA compared to 4–10 minutes with MWA. Both ablation modalities allow for placement of multiple probes at the same time. Because the EM field in MWA probes can reflect and heat the probe along the shaft or by interference if two transcutaneous probes are placed too close together, skin and abdominal wall injuries can occur with MWA during minimally invasive ablation that are not seen with RFA (Figure 75.19).

In summary, it is essential for the surgeon to familiarize himself or herself with the ablation system and modality being used and gain experience with its tissue effect under many different circumstances. Current ablation systems for minimally invasive liver procedures are in constant evolution, and a proprietary system continually addresses the drawbacks inherent to each system.

CLINICAL OUTCOMES AND TRIALS FOR RADIOFREQUENCY ABLATION AND MICROWAVE ABLATION

The use of thermal ablation modalities has become part of the routine armamentarium for hepatobiliary surgeons. Surgical resection of liver cancer, primary or metastatic, is still the gold standard to obtain best 5-year overall survival.²³ However, many patients will present with surgically unresectable tumors either because of location, disease burden, comorbidities, or palliative indications. In these patients, thermoablative techniques are excellent options in the management of their disease. A recent systematic review of 34 studies and over 10,000 patients undergoing MWA and RFA showed very low overall major complications and mortality rates of 3.29% and 0.16%, respectively. RFA and MWA carried a major complication rate of 4.1% and 4.6%

Table 75.3 Complications of MW ablation

Injury	How to prevent injury	Life threatening
Skin burns	Proper spacing (>1.5 cm apart) and >3 cm from radiating tip	No
Liver abscess	Perioperative antibiotics	Yes
Liver infarcts	Avoid ablation near portal pedicle	Yes
Vascular fistula	Avoid ablation near portal pedicle	Yes
Bile duct injury	Avoid ablation near portal pedicle	Yes
Hemolysis	Avoid ablation on inferior vena cava	No
Adjacent organ injury	Adequate distance between	

Table 75.4 Differences in physical properties of MWA and RFA

	RFA	MWA
Frequency	375–480 kHz	915 MHz–9.2 GHz
Wavelength in tissue	Meters	Centimeters
Mode of energy transfer	AC current	EM waves
	Requires multiple dispersive electrodes and closed circuit	No circuit required
Primary heating mechanism	Resistive at highest current density (RF probe tip)	Dielectric heating within MW near-field (direct effect of EM waves on water molecules)
		Responsible for most of the ablation volume
Secondary heating mechanism	Conductive heating away from RF probe tip into surrounding tissue	Conductive heating from MW near-field into surrounding tissue
	Responsible for most of the ablation volume	

and a mortality rate of 0.15% and 0.23%, respectively, without significant differences.²⁴

RFA has been the first and most widely used ablation technique for liver lesions. However, clinical study results have shown high rates of recurrences in larger lesions, but

recurrence rates up to 20% and higher have been reported even for lesions 3 cm or smaller.^{25–31} These suboptimal results are being explained by the heat-sink effect seen with RFA, the difficulty of monitoring RFA with intraoperative US, and evidence that some tumor cells might even survive within the observed ablation zone.^{32–35} The high recurrence rates for thermal ablation of liver lesions seen in the initial experience with RFA have led surgeons to restrict ablation to lesions around 3 cm or less. Several studies have shown that local recurrence rates markedly increase with ablation of hepatic lesions over 3 cm.^{18,29,30,36,37}

Randomized studies comparing RFA and MWA are lacking. A large analysis of all available randomized trials comparing RFA for hepatocellular cancer to surgical resection, to no intervention, to placebo, and to other non-surgical interventions published in 2013 demonstrated superiority of surgical resection over RFA regarding survival. RFA was also found to carry less complications and shorter hospital stays compared to surgery. RFA was found to be superior to percutaneous alcohol injection for survival. There was not enough data from randomized studies to evaluate superiority of RFA versus MWA or other ablation techniques. The data did not allow any conclusion regarding the role of RFA versus no intervention, chemotherapy, or liver transplantation.³⁸ A recent retrospective matched cohort analysis comparing MWA and RFA for colorectal cancer metastases of the liver showed a significantly lower initial local recurrence rate for MWA (6% versus 20%) and predicted 2-year recurrence rates (7% versus 18%).³⁹ This confirmed findings by other groups comparing RFA and MWA, showing very low local recurrence rates for MWA of less than 10%.⁴⁰ Similar results were obtained in a Phase II multi-institutional study demonstrating local recurrence rates after liver lesion MWA of 4% with 47% of living patients showing no evidence of disease at 19 months mean follow-up. Eighty-seven patients underwent 94 liver ablations with the majority performed open and laparoscopically (53%). The average liver lesion size was 3.6 cm (range 0.5–9.0 cm). Individual lesion local recurrence rate was 2.7% (six lesions).⁴¹ These results would be very difficult to match with current RFA technology, and it appears that

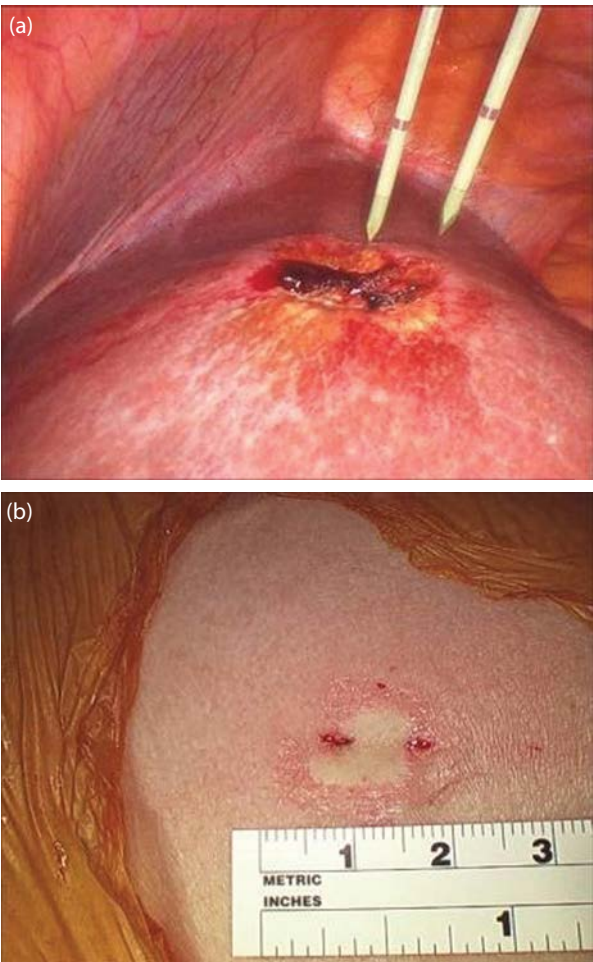


Figure 75.19 Transcutaneous MWA probes used during minimally invasive ablations (a) can cause full-thickness burns to the abdominal wall insertion site if placed closer than 1.5 cm apart (b).

MWA does have some advantage in terms of lesser local recurrence rates after treatment of liver lesions. Although most of the reported experience on ablation of liver lesions comes from studies with RFA, MWA is gaining acceptance among surgeons because of its favorable results, despite the lack of level 1 evidence.

Results for hepatocellular carcinoma

Studies evaluating MWA and RFA specifically in the setting of laparoscopic ablations of liver tumors have shown excellent results equivalent to open ablation procedures. Hepatocellular carcinoma (HCC) is particularly suited for the use of minimally invasive thermal ablation. This is due to the relative small size at diagnosis resulting from increased surveillance of patients at risk and to the fact that HCC carries a relatively higher water content compared to the often fibrotic or cirrhotic liver surrounding it. Most HCCs are diagnosed at the relatively small size of 3 cm or less and thus present with a relative sharp demarcation from the surrounding liver parenchyma without signs of overt invasive growth. Several groups have successfully proved the efficacy of microwave ablation in the treatment of hepatocellular carcinoma.^{39,40} Incomplete ablation rates for laparoscopic MWA and RFA of HCC vary from 5.6% to 13%. Local recurrence rates are reported between 2.9% and 22%.^{42–45} Published survival rates after laparoscopic thermal ablation for HCC are around 70%–80% at 1 year and 20%–40% at 3 years.^{46–48}

Results for colorectal liver metastases

Liver ablation results for colorectal liver metastases (CRLMs) are less impressive, as these lesions are more difficult to ablate than HCC due to their relative lack of water content and location near large vessels. However, since only 20% of CRLMs are surgically resectable, thermal ablation modalities play an important role in their treatment. Local recurrence rates after laparoscopic ablation of CRLM range from 9.2% to 34%. It has been shown that obtaining larger ablation margins of 2 cm or more reduces the local recurrence rate after CRLM ablation.^{49–52} Survival rates after laparoscopic CRLM ablation do not reach those observed after resection. For tumors 3 cm or less, the reported survival rate after laparoscopic ablation is 47%.⁵³ An interesting study compared survival rates after ablation of CRLM deemed either resectable or unresectable. Those found retrospectively by image analysis to be technically resectable had a 5-year survival rate of 48.7% versus 18.4% for those deemed unresectable.⁵⁴

Results for other liver lesions

Results for other liver lesions such as secondary metastases from neuroendocrine tumors or other organs are difficult to evaluate because of lack of data. It is noteworthy that neuroendocrine metastases are particularly suited for thermal

ablation due to their very high water content and usually sharp demarcation to the surrounding liver parenchyma. Benign liver lesions in general are not good candidates for thermal ablation as the therapeutic intervention becomes relevant at a relatively large size at which ablation is unlikely to be successful. Hemangiomas and liver cysts should not undergo thermal ablation for treatment.

Thermal ablation modalities have evolved into a standard therapy for liver lesions. MWA is increasingly utilized as the primary modality because of its apparent advantages over RFA and other modalities such as cryotherapy and alcohol injections. Single-center studies have demonstrated significant improvements in completeness and local recurrence for MWA,⁵⁵ although this has never been proven with a prospective, randomized trial. Appropriate patient selection, excellent knowledge of the used ablation system, and image-guidance modality are critical for a successful liver ablation, open or laparoscopic.

CONCLUSION

Laparoscopic ablation of liver lesions is a rapidly advancing field in hepatobiliary and oncologic surgery. Although the technology has been available for over 100 years, major advances and development into standards of practice have occurred only recently. The most advanced systems today rely on microwave energy, which provides the most consistent and reproducible results within a very effective time frame. However, these systems are in constant evolution; therefore, the laparoscopic surgeon using these techniques in practice needs to stay flexible and abreast of the technological changes in this field.

VIDEOS

Video 75.1 Accurate placement of an active RFA probe during an open liver ablation procedure and demonstration of the "parallel" placement technique (<https://youtu.be/tlMwZocTLTw>).

Video 75.2 Parallel US guidance of an MWA probe for ablation of a primary hepatocellular cancer in a cirrhotic liver (<https://youtu.be/APgYpKgVcPI>).

Video 75.3 Laparoscopic US-guided placements of an MWA probe in 45° and 90° angles (<https://youtu.be/8Jfw1dfC8jk>).

Video 75.4 Appropriate laparoscopic placement of MWA antenna into target lesion at an angle (<https://youtu.be/ix7INsn9R1l>).

Video 75.5 The simultaneous laparoscopic placement of two MWA probes for the ablation of a larger hepatic tumor. Please note the device that maintains the safety distance of at least 1 cm at the skin insertion site to prevent skin burns (<https://youtu.be/603A3JTiclc>).

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Robotic approach to hepatic resections

SUSANNE WARNER AND YUMAN FONG

INTRODUCTION

Liver surgery was once considered a dangerous endeavor with prohibitive risks except in dire circumstances. However, with improvements over the last 30 years in anesthesia and critical care, as well as enhanced preoperative imaging and thereby improved surgeon preparation for anatomical considerations of resection, liver resection has become a safe tool for a number of hepatic maladies with a mortality rate of less than 1% in the modern era.^{1,2} However, the morbidity of open liver resection remains considerable with rates as high as 42%–45% in major series,^{2,3} and postoperative morbidity has been associated with adverse disease-specific survival.^{3,4} While morbidity of major liver resection is a significant consideration regardless of technique, minimally invasive liver resection has the potential to minimize adverse events, and portends decreased estimated blood loss, decreased length of stay, and perioperative pain.^{5–9} The case for minimally invasive techniques in peripheral liver resections (segments II, III, V, and VI) is clear, and most experts agree, this should be the standard of care in the current era.^{10,11} As worldwide experience with minimally invasive hepatic resection grows, advanced minimally invasive resections are increasingly being performed, and evidence is improving for the safety and feasibility of minimally invasive major hepatectomy (resection of greater than or equal to four segments), and for minimally invasive resection of more cumbersome lesions, like those in segments I and VII.^{11–14}

While laparoscopy is gaining acceptance for hepatobiliary resections, robotic surgery offers unique advantages over laparoscopy, such as enhanced ergonomics, improved range of motion with wristed movement, elimination of tremor, three-dimensional visualization, and an ever-growing armamentarium of tools that are well suited to many different arenas of surgery. Robotic surgery also offers excellent counter points for many of the arguments against minimally

invasive liver surgery. As the “great equalizer,” robotic surgery eliminates tremor and muscular fatigue that can come with operating for long periods laparoscopically, and there are several publications to suggest that the learning curve from open to robotic surgery, while steep, is more quickly surmountable, making the skillset required for advanced robotic surgery much more accessible than that required for laparoscopic intervention.¹⁵ Disadvantages of robotic liver surgery include a high fixed cost of the robotic surgical system, and the absence of haptic feedback. However, innovative new platforms are currently in development and with them will come the elimination of a robotic monopoly and hopefully decreased overall systems costs. A review of robot liver surgery published in 2013 found that fewer than 300 cases with credible follow-up and clinical characteristics had been published.¹⁶ Other authors have shown that use of a robotic platform in the United States has changed dramatically over the last 8–10 years and is likely to do so in the coming years as well.¹⁷ This chapter reviews the current literature regarding robotic liver resection and presents tools utilized to achieve resection.

ROBOTIC VERSUS LAPAROSCOPIC TECHNIQUES IN THE LITERATURE

In one of the few currently available matched comparisons between laparoscopic and robotic liver resection, Tsung and colleagues reviewed their own experience comparing 113 laparoscopic matched control patients with 57 robotic liver resection patients and found that the robotic cohort contained substantially more major hepatectomies (37%) than the laparoscopic cohort (7%), and that robotic techniques facilitated pure minimally invasive approach in 93% of attempted patients, whereas a hand-assisted or hybrid approach was utilized in 51% of laparoscopic cases.¹⁸ No differences in major complications were seen, and RO

resection was achieved in 95% of robotic surgeries and 92% of laparoscopic surgeries. However, when robotic and laparoscopic minor liver resections (defined as resection of three or fewer liver segments) were compared, robotic intervention conferred significantly higher estimated blood loss (EBL) (mean 285 versus 50 mL, $p = 0.011$) and significantly longer operating room time (198 minutes versus 163 minutes, $p < 0.001$).¹⁸ That being said, the authors accounted for the effect of technical learning curve and reported more favorable outcomes in the later cases.¹⁸ In a similar study, Lai et al. reviewed their experience with 33 patients undergoing robotic liver surgery for hepatocellular carcinoma and compared operative and patient characteristics with a previous cohort of patients who underwent laparoscopic liver surgery. They found no significant difference between groups apart from an increased operative time in the robotic surgery group.¹⁹ They also observed that the robotic-assisted technique afforded the opportunity to complete more major hepatic resections as compared to resection of smaller peripheral or more easily accessible lesions. In general, the presently accepted clear advantages of the robot over laparoscopic surgical techniques include decreased blood loss and fewer conversions to laparotomy.²⁰

ROBOTIC VERSUS LAPAROSCOPIC LEARNING CURVE

Robotic liver resection offers a unique platform that has been shown to facilitate a less difficult transition from open techniques than from open to laparoscopic techniques.¹⁵ Multiple studies demonstrate superior robotic skill acquisition in naïve users as opposed to laparoscopic skills.²¹ This is part of the appeal of robotic surgery, because many surgeons who were not trained in the laparoscopic era, or who lack advanced laparoscopic skills are unable to safely offer minimally invasive liver surgery without dramatic time investments and alterations in practice patterns. Conversely, motions and dissection techniques used during robotic surgical intervention are much more similar to those used in open surgeries and in some cases—like elimination of

tremor, and utilization of 270° of wristed motion—surpass the dexterity available to the human hand. Opponents of the currently available robotic platforms point out that the absence of haptic feedback is a source of potential danger in terms of inappropriate tissue handling. While this may be true, this barrier can easily be overcome with practice in a simulated dry dock setting and over time experienced robotic surgeons describe a sort of visual haptic sensation that develops.²² Tsung and colleagues examined their experience with the first 13 robotic resections occurring before January 2010 and the latter 44 and found significant differences in mean EBL (300 versus 100, $p = 0.008$), overall room time (466 versus 315 minutes, $p = 0.001$), and length of stay (5 versus 4 days, $p = 0.031$).¹⁸ This is similar to the learning curve experience that others have described for robotic Whipple procedures.²³ One must also bear in mind that a surgeon wishing to build a robotic surgery program should seek proper assistance during initial procedures from proctors who are familiar with robotic hepatobiliary surgical techniques. The grade of the steep learning curve can thereby diminish dramatically, and safe and efficient robotic surgeries can be achieved in relatively short order.

INDICATIONS AND TECHNIQUES OF ROBOTIC LIVER RESECTION

As with any liver surgery, minimally invasive interventions require careful patient selection both in terms of resectability and patient ability to tolerate a procedure. Contraindications as they relate to anticipated robotic resection are detailed in [Table 76.1](#). Many different techniques have been reported for robotic liver surgery. As always, when utilizing the da Vinci Si platform, the “20-10-5” rule is applied in selecting proper port placement. That is, position the camera 20 cm from the operative target, robotic ports should be 10 cm apart, and assistant ports should be a minimum of 5 cm from the nearest robot port. Some authors describe a split leg supine position with 20° of reverse Trendelenburg.^{24,25} This rule is a bit more malleable with the use of the da Vinci Xi platform as robotic arm collisions are not as much of a factor. It is our

Table 76.1 Contraindications for robotic surgery

Relative contraindications	Absolute contraindications
• Moderate cardiopulmonary limitations with recent exacerbations • Tumor >6 cm^a • Cirrhosis/fibrosis presenting technical difficulties with parenchymal transection • Vascular involvement requiring primary repair • Extensive prior abdominal surgery • History of radiation or cholangitis with anticipated periportal inflammation or fibrosis	• Inability to tolerate pneumoperitoneum • Pulmonary hypertension • Severe chronic obstructive pulmonary disease • Untreated visceral or aortic aneurysmal disease • Other cardiopulmonary comorbidities or ASA>3 • Insufficiently skilled surgeon^b • Major vascular involvement requiring extensive reconstruction • Prior extensive hepatic surgery • Child's B or C cirrhosis

^a Tumor greater than 6 cm can be considered if peripherally located and/or exophytic.
^b Initial attempts at complex resection should be performed in the presence of an experienced robotic surgeon.

practice to choose position and port placement based on anatomic considerations of resection. For instance, higher lesions may require more reverse Trendelenburg and high right-sided lesions may necessitate rightward shift of ports and even left lateral decubitus positioning. Body habitus must also be considered for each particular patient. Thus, more obese individuals may require ports placed in a more supraumbilical distribution, and more slender patients may require more infraumbilical port alignment. In general, for right hepatic resection, robot docking is performed over the right shoulder, whereas for left hepatic resections the robot is docked over the patient's head or left shoulder depending on patient habitus and tumor location. Typical room setup and port placements are shown in **Figures 76.1** and **76.2**.

Any robotic liver surgical procedure will have six general phases: (1) Laparoscopic exploration abdominal entry and assessment. During this phase, laparoscopic ultrasonography can be performed prior to robot docking as a part of initial exploration to confirm preoperative imaging

findings and to establish anticipated planes of resection. Alternatively, if a “drop-in” ultrasound probe is put to use, the robot can be docked after initial abdominal surveillance and port placement. (2) Dissection of portal structures is dictated by disease process and location and achievement of vascular control where appropriate. This includes inflow occlusion via selective ligation of portal vein and hepatic arterial branches or Pringle maneuver, and outflow occlusion if sectionectomy or lobectomy is anticipated with encircling and/or ligation of appropriate hepatic vein(s). (3) Hepatic mobilization can be achieved employing a variety of different robotic tools—typically a mix of sharp and thermal dissection with or without a robotic or laparoscopic energy sealing device. (4) Parenchymal transection. As with laparoscopic liver surgery, many groups employ an energy device for capsular entry and then turn to laparoscopic staplers to contain larger vessels and bile ducts. This is guided by ultrasonography. Our practice is to mark out the plane of transection with robotic monopolar scissors

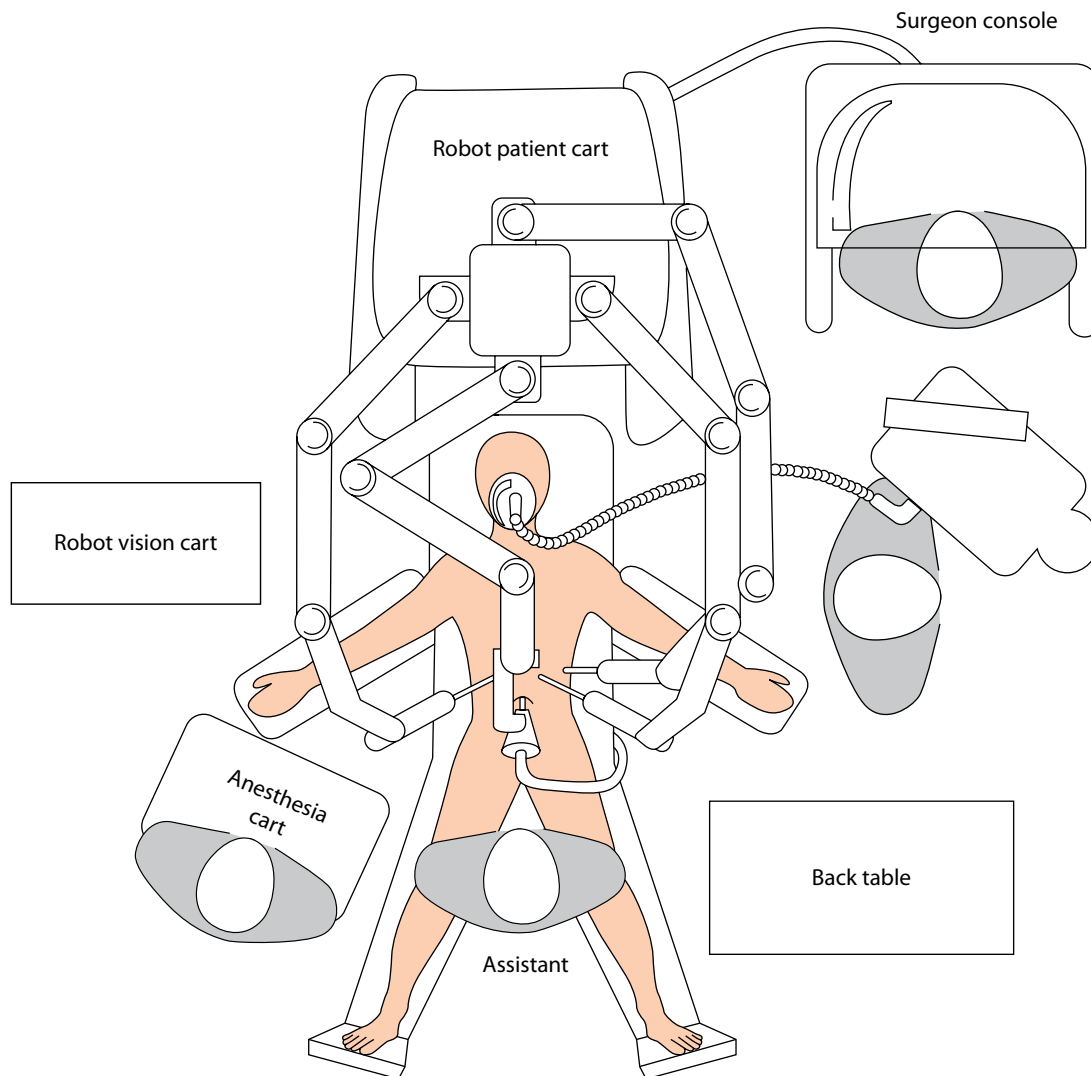


Figure 76.1 Operating room setup for robotic liver resection.

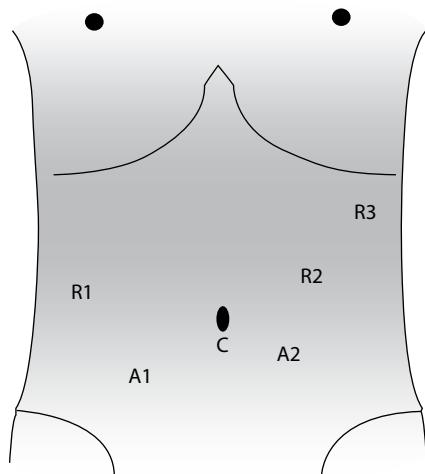


Figure 76.2 Typical port placement for hepatic resection. (C, camera. R1, R2, R3, robot arms 1, 2, and 3; A1, assistant port, 12 mm; A2, optional second assistant port, 5 or 12 mm. Can shift entire setup rightward for posterior lesions, including camera off midline to patient's right, with patient in modified left lateral decubitus position as needed. R2 and R3 can be adjusted based on side of lesion, patient body habitus, and liver size and shape.)

or hook (**Figure 76.3a and b**). The first centimeter or so of parenchymal transection is then performed using monopolar energy. As dissection deepens, a robotic energy device can be used for clamp/crushing as well as vessel and duct sealing. The fenestrated bipolar grasper can assist with any small structures that may be torn (**Figure 76.3c**). Ultimately, larger pedicles are skeletonized and laparoscopic staplers can be employed. (5) Specimen extraction using a laparoscopic retrieval bag in order to keep the specimen entirely together. If the specimen is large, fascial closure of the extraction site will be necessary to facilitate reinsertion. (6) Evaluation of resection bed for hemostasis and presence of bile.

As with any minimal access surgery, it is helpful to establish predefined criteria for when or if one would convert to an open technique. While circumstances for each patient and each liver are of course unique, general criteria for conversion should include patient instability requiring efficient case completion that is facilitated by open techniques, excessive (>500 mL) blood loss not controllable via robotic techniques or requiring manual compression, unexpected hilar injury during dissection compromising future liver remnant, and cases with unclear anatomy.

OUTCOMES OF ROBOTIC LIVER SURGERY

The data here are as yet extremely limited. However, in currently available literature, robotic surgery appears to confer similar advantages as laparoscopy, like decreased length of stay, decreased morbidity, faster return to function, lower narcotic requirement, and in some studies significantly lower EBL,^{18,26,27} all without compromising oncologic outcomes as

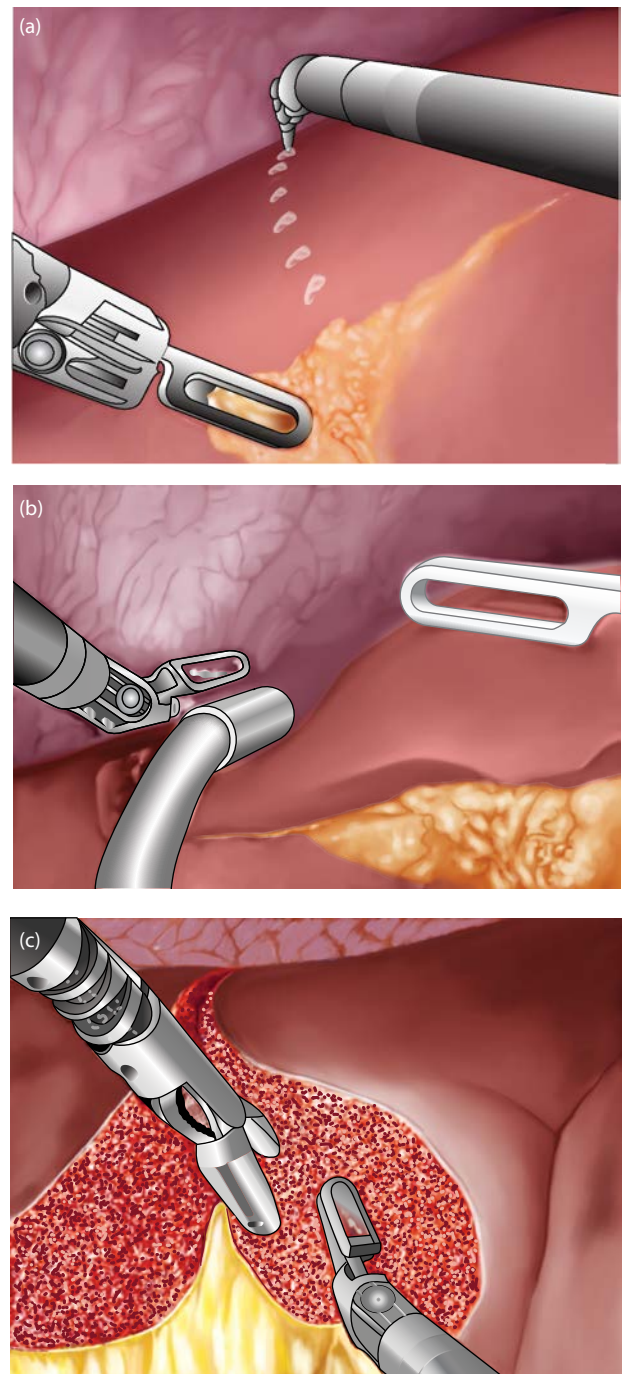


Figure 76.3 Parenchymal transection. (a and b) The transection plane is marked off with robotic scissors or other monopolar cautery source as guided by ultrasound to achieve appropriate margins. (c) Robotic energy device is used for deeper parenchymal division as a clamp/crush and sealing device. Fenestrated bipolar is used to seal smaller cut service vessels and ducts.

compared to open surgery in most instances.¹⁹ Currently the absolute patient safety data are unknown. Many surgeons make initial forays into utilization of new techniques, and some have disastrous complications, many of which go

unreported. An excellent review of available robotic pancreatic surgery literature details inconsistencies even among reported cases.²⁸ For robotic liver surgery, the data are even more sparse.¹⁴ Those endeavoring to build a robotic program should ensure that patient safety is prioritized.

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Laparoscopic staging for pancreatic malignancy

AMMARA A. WATKINS AND MARK P. CALLERY

OVERVIEW

Pancreatic cancer is a devastating disease with 5-year survival estimates approaching less than 6% for patients with pancreatic ductal carcinoma. Surgery remains the mainstay treatment for resectable disease and confers some survival advantage to the patient. Accurate staging is therefore critical in treatment. The majority of patients with pancreatic cancer undergo radiological staging via computed tomography (CT) imaging. However, a large subset of patients initially deemed resectable (approximately 10%–20%) undergoes unnecessary laparotomy because of underestimation of the extent of cancer after CT staging.^{1,2} Modern CT imaging appears able to capture unresectable disease well but falls short in predicting resectable disease.

Diagnostic laparoscopy was developed as an add-on test to CT to reduce unnecessary laparotomy and subsequent morbidity.³ While accumulating single institution series have largely favored the use of diagnostic laparoscopy in staging pancreas cancer, there remains significant controversy surrounding its routine or selective use. Those who embrace diagnostic laparoscopy believe that, should unresectable disease be found, palliation is best pursued non-operatively. Others believe that palliation is best achieved via a surgical, open technique. This chapter focuses on the highest-level data and expert consensus guidelines available on the subject in aims to guide management for patients with pancreatic cancer.

PREOPERATIVE COMPUTED TOMOGRAPHY IMAGING

Currently, multidetector CT with three-dimensional reconstruction including vasculature is the preferred method to preoperatively stage pancreatic cancer and identify patients eligible for resection with curative intent.^{4–6}

This is consistent with expert consensus and National Comprehensive Cancer Network guidelines.^{4,7} Magnetic resonance imaging (MRI) and positron emission tomography (PET) scans are increasingly used as an adjunct to CT scans. However, data are accumulating on their capabilities of determining resection. The use of MRI and PET scans has not demonstrated cost-benefit to warrant routine use and remains controversial in preoperative staging.⁸ CT remains the gold standard despite some shortcomings. CT has been shown to have a high predictive value of unresectability (90%–100%) with a slightly lower predictive value of resectability (76%–90%).⁴ This is attributed to CT's inability to detect occult liver metastasis and peritoneal spread.⁴ This problem is compounded by the presence of benign small liver lesions such as cysts, hemangiomas, or bile duct hamartomas in normal patients.

PREOPERATIVE MAGNETIC RESONANCE IMAGING

Given MRI's greater soft tissue penetration, MRI does have some advantage over CT in specific scenarios for preoperative diagnosis and staging. In these situations, MRI is a useful adjunct to preoperative CT, particularly in further characterizing indeterminate lesions. MRI is superb in characterizing small masses of the pancreas, specifically those that do not deform the contour of the pancreas or are less than 2 cm.⁹ It is also useful in characterizing a large pancreatic head without a distinct, visualized mass on CT and in distinguishing chronic pancreatitis and groove pancreatitis from a suspicious tumor.¹⁰ Isoattenuating pancreatic cancers and fatty infiltrations of the pancreatic head confused for tumors can also be more reliably diagnosed with MRI.⁹ Finally, MRI is also helpful in characterizing small hepatic lesions that are difficult to distinguish from benign lesions on CT.⁹

DIAGNOSTIC LAPAROSCOPY

Studies have demonstrated that approximately one-third of patients presumed to be resectable based on CT imaging will be disqualified for surgery at the time of laparoscopic staging.^{11,12} Despite the apparent benefits, the value of staging laparoscopy is not universally accepted. Opinions vary from recommending routine use to not performing it under any circumstances.

A key goal in patients with advanced pancreatic cancer is to avoid laparotomy if possible and facilitate care into non-operative palliation to protect quality of life.¹³ Diagnostic laparoscopy aims to reduce unnecessary laparotomies by providing more in-depth assessment of a patient's cancer stage. A periumbilical port is placed to insert a 30° angled scope. Assisting trocars in the upper midabdomen or right upper quadrant may also be placed to help visualize all structures. During the procedure, key areas of tumor spread are examined. This includes the falciform ligament, the lesser sac, underneath the transverse mesocolon, along the surface of the bowel, the root of the ligament of Treitz, along the paracolic gutters and pelvis. Ultrasound can also be utilized to identify intrahepatic metastatic lesions, the degree of tumor involvement on the portal vein, superior mesenteric vein, porta hepatis, major arterial involvement, and pathologically involved lymph nodes beyond the boundaries of dissection. Should biopsies be needed to guide neoadjuvant therapy, laparoscopic ultrasound can provide additional visualization of the biopsied site. In the event of locally advanced disease, CyberKnife gold fiducial seeds may also be placed as future targets for stereotactic

radiation. Cytological analysis can also be obtained during diagnostic laparoscopy, although positive results are difficult to evaluate, as there is variation of accuracy at predicting disseminated disease. Furthermore, the results are not usually available in real time.

Procedure-related morbidity from diagnostic laparoscopy ranges from 0% to 4%.¹⁴ Complications are primarily minor and include wound infections and port site bleeding. Mortality rates are 0% in the majority of the literature.¹⁴ Conversions to open are rare,¹⁵ and hospital stay is typically brief.³ As compared to open laparotomy, diagnostic laparoscopy has shorter hospital stay, lower costs, and shorter times to initiation of chemotherapy.^{14,17} Early concerns of port-site recurrence after laparoscopic procedures for cancer patients have now been dismissed. Numerous studies report a 0%–2% incidence of port-site recurrences which is similar to open explorations for cancer patients.¹⁴

CONTEMPORARY EVIDENCE-BASED ANALYSIS

The highest-level available data are systematic reviews of cohort studies.^{14,18} The most recent systematic review is within the Cochrane Database assessing accuracy of diagnostic laparoscopy following CT scanning.¹⁸ Data from the systematic review are summarized in [Table 77.1](#). Fifteen studies (1,015 patients) were included in this meta-analysis. Median pretest probability for unresectable disease was 40.2% across all studies (indicating 40 out of 100 patients who had resectable cancer after CT scan were found to have unresectable disease

Table 77.1 Summary of findings of Allen et al.¹⁸ systematic review

Population	Patients aged 15–87 years with potentially resectable pancreatic or ampullary carcinoma on CT	
Setting	Centers in the United States, Germany, United Kingdom, Japan, and Israel	
Index test	Diagnostic laparoscopy with histologic confirmation	
Number of studies	15	
Summary sensitivity	68.7% (95% CI 54.3%–80.2%)	
Overall risk of bias	High	
Pretest probability from included studies	Post-test probability of unresectable disease for patients with a negative test result (95% CI)	Percentage of patients for whom unnecessary laparotomy may be avoided
Minimum = 17.4	6.1 (4.2–9.2)	11.3
Lower quartile = 34.2	13.9 (9.8–20)	20.3
Median = 40.3	17.3 (12.4–24.5)	23.0
Upper quartile = 62.8	34.4 (26.2–44.8)	28.4
Maximum = 81.8	58.2 (48.6–58.3)	23.6
Interpretation	With pretest probabilities of 17%, 40%, and 82%, adding laparoscopy to CT scan for the preoperative staging of pancreatic cancer avoids 11, 23, and 24 unnecessary laparotomies out of 100 laparotomies. These pretest probabilities are the minimum, middle, and maximum values obtained from included studies.	

Source: Modified from Allen VB et al. *Cochrane Database Syst Rev* 2013;11:CD009323.

at laparotomy). The summary sensitivity for diagnostic laparoscopy was 68.7% (95% CI, 54.3%–80.2%). The calculated post-test probability of unresectable disease for patients with a negative test result was 0.17 (95% CI 0.12–0.24). These data indicate that if a patient is said to have resectable disease after CT scanning and diagnostic laparoscopy, there is only a 17% probability that their cancer will be unresectable. This is in comparison to a 40% probability to the standard practice of CT scan staging alone.

A subgroup analysis of patients with pancreatic cancer yielded similar results.¹⁸ The post-test probability of unresectable disease after being considered resectable after CT scanning and diagnostic laparoscopy was 18% compared to 40% for those receiving CT scan alone.¹⁸ This is to say that on average, diagnostic laparoscopy with subsequent histopathological confirmation of suspicious lesions prior to laparotomy would avoid 23 unnecessary laparotomies in 100 patients in whom resection with curative intent is planned.

This review is not without weaknesses. The majority of studies have low methodological quality, and there is notable heterogeneity between the studies. Additionally, 11 of the 15 articles were conducted more than 10 years ago.¹⁸ This may have implications for the systematic review's applicability to modern, improved CT imaging capabilities. That would also presume that CT capacity to detect occult metastasis has improved over the same time period; however, this remains in question. Nevertheless, this is the highest-level and most current data available in guiding treatment that is consistent with the only other systematic review on the topic.¹⁴ Prior systematic review has found diagnostic laparoscopy may avoid unnecessary laparotomy in 4%–36% of patients.¹⁴

EXPERT CONSENSUS GUIDELINES

The Expert Consensus statement⁴ on the topic advocates selective laparoscopy rather than routine use on the basis of clinical predictors that optimize diagnostic yield.¹⁹ Larger tumors and tumors of the neck, body, and tail of the pancreas that are more likely to metastasize are recommended to undergo staging laparoscopy.²⁰ Additionally, equivocal masses on CT and patients presenting with high carbohydrate antigen (CA) 19-9 often signify metastatic disease.¹⁶

It is therefore recommended that selective laparoscopy be pursued among patients with characteristics highlighted in [Table 77.2](#). For patients with locally advanced unresectable pancreatic cancer without radiographic evidence of distant metastasis, staging laparoscopy may also be used to rule out subclinical metastatic disease to optimize treatment selection.

Data are accumulating on the usefulness of peritoneal cytology at the time of diagnostic laparoscopy. When positive cytology does upstage the patient's disease to AJCC

Table 77.2 Patient characteristics that would benefit from selective laparoscopy

- Pancreatic head tumors >3 cm
- Tumors of the pancreas body and tail
- Equivocal findings on CT
- High CA 19-9 levels (>100 U/mL)
- Worrisome clinical features (marked weight loss and/or pain, hypoalbuminemia)

Source: Data from Callery MP et al. *Ann Surg Oncol* 2009;16:1727–33.

Stage IV, this affects disease progression and survival. Diagnostic accuracy of cytology is variable at centers, and many surgeons remain skeptical. The current expert consensus recommendation is that further studies on molecular and genetic marker analysis are needed before positive cytology results are treated as Stage IV disease.

SUMMARY AND OVERALL RECOMMENDATION

Based on the available highest-level data and expert consensus guidelines, staging laparoscopy with ultrasound should be selective. It should be pursued for patients with pancreatic head tumors larger than 3 cm, tumors located in the body or tail of the pancreas, high CA-19-9 levels, and those with CT scans representing equivocal metastatic disease.

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Robot-assisted minimally invasive pancreaticoduodenectomy

ALESSANDRA STORINO, TARA S. KENT, AND A. JAMES MOSER

INTRODUCTION

Surgical care of patients with periampullary tumors has been in the phase of evolution since Walter Kausch first pioneered pancreaticoduodenectomy (PD) for ampullary carcinoma in 1909. The first phase consisted of major revisions to Kausch's original procedure, which made surgical resection of the pancreatic head technically feasible: Whipple's introduction of a single-stage technique to restore gastrointestinal (GI) continuity in 1935; and Longmire's incorporation of pylorus preservation in 1978. The second phase began in the 1970s with rapid reductions in postoperative mortality made possible by improvements in intensive care medicine at specialized centers of excellence.¹¹ The third phase began in 1994 when Gagner and Pomp performed the first laparoscopic PD, which was clearly the most ambitious application of minimally invasive surgery since its inception by Muehl in 1984.¹⁷

Although recent series of minimally invasive PD demonstrate outcomes comparable to open PD in selected patients, widespread adoption of laparoscopic techniques has been delayed and remains concentrated at specialized centers.¹ The slow implementation of laparoscopic PD demonstrates the need to update surgical training for complex surgical procedures and overcome design limitations of current laparoscopic instrumentation. These instrument limitations have been partially reduced by robotic technologies incorporating magnified stereoscopic visualization, elimination of the surgeon's tremor, and reproduction of the natural motion of intracorporeal instruments. Computer-controlled instrumentation allows complex resections and reconstructions to be performed with minimally invasive techniques duplicating traditional open methods. The first reports of robot-assisted pancreatic resection appeared in 2003. Giulianotti et al.

published results on 13 pancreatic resections in Europe⁴, while Melvin et al. published a description of a robotic resection of a pancreatic neuroendocrine tumor in the United States.⁵ Subsequent series of robot-assisted PD demonstrate the safety and feasibility of this technical approach, and emerging comparative effectiveness data between open and minimally invasive PD demonstrates preliminary equivalence.²

SAFETY AND SELECTION

Safety and transparency of surgical outcomes are critical during early adoption of a new surgical procedure. All potential candidates for robotic PD should participate in a registry approved by an institutional review board (IRB). Procedures should be performed by an expert team familiar with open PD and capable of venous resection and reconstruction whenever indicated. We advise creating a surgical team with advanced minimally invasive skills and believe that proficiency in robot-assisted PD is not achieved until approximately 50 cases have been performed. Surgical trainees are incorporated into the surgical team in a stepwise fashion, as their training and expertise with robotic technology permit.

The positioning challenges and access issues created by the current generation of large, immobile robotic instruments deserves comment. Patients with active cardiovascular disease and renal insufficiency are not ideal candidates. The procedure requires reverse Trendelenburg positioning with its effects on preload, urine output, and blood pressure. Bleeding from major vessels in this position is potentially hazardous and must be controlled rapidly without undocking. Proper preparation by the anesthesia team is required because the patient is not accessible once the robot is positioned. Adequate intravenous (IV) access, invasive monitoring lines, and

endotracheal and nasogastric intubation must be obtained and safeguarded during the procedure. Finally, the expected pathology and anatomy of the underlying lesion must be considered. It is a general rule that the most difficult resections require the simplest reconstructions. For example, obstructing lesions causing biliary and pancreatic duct dilation and parenchymal fibrosis are associated with the least challenging reconstructions but raise the risk of adherence to the portal vein (PV) with increased risk of venous injury.

THE PREOPERATIVE CHECKLIST

The patient is placed in the supine position on a split leg table to maximize instrument access for the seated laparoscopic surgeon (Figure 78.1). The robotic console should be located to permit a direct line of sight between the robotic surgeon, the laparoscopic surgeon, and the scrub technician for communication purposes. This cannot be emphasized enough, as remote surgery creates uncharacteristic communication challenges for the surgical team. A nasogastric tube and urinary catheter are required. The right arm is tucked to prevent collisions between the patient's shoulder and the robot. The patient's left arm is outstretched to afford anesthesia access to the pulse oximeter, blood pressure cuff, and arterial line. Body temperature is maintained with an upper body warming blanket.

TROCAR PLACEMENT

Trocar placement is designed to facilitate the procedure that occurs in three phases: staging laparoscopy, laparoscopic mobilization of the pancreatic head, and robot-assisted resection and reconstruction. Once resectability is confirmed, seven ports are required (Figure 78.2).

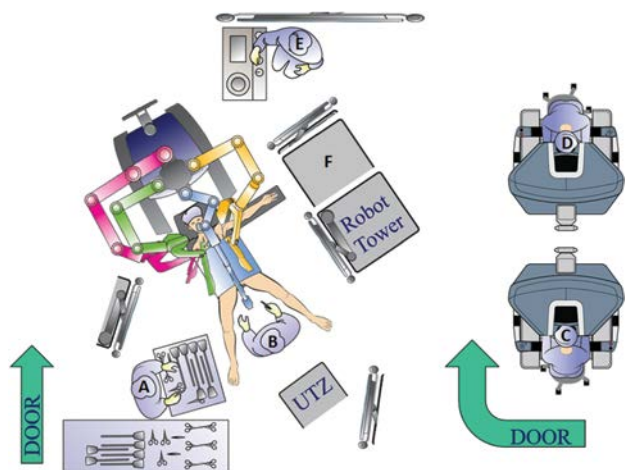


Figure 78.1 Operating room setup. (a) Surgical technician. (b) Laparoscopic surgeon sitting between the legs of the patient. (c) Console surgeon operating the robot. (d) Surgical trainee or observer. (e) Anesthesiology team. (f) Supporting equipment.

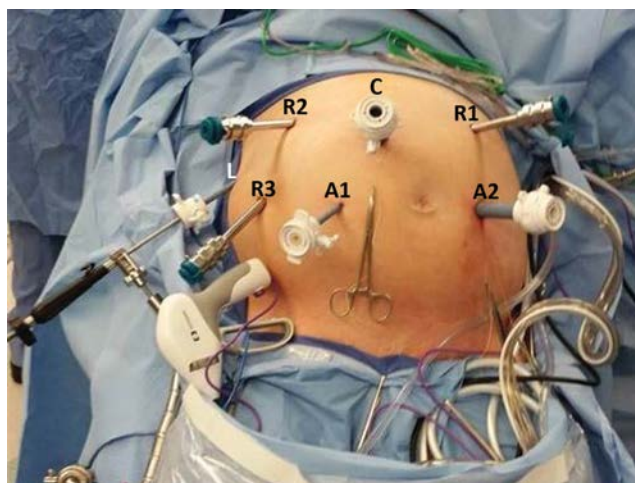


Figure 78.2 Suggested location of ports for robot-assisted pancreaticoduodenectomy. A 5.5 mm optical separator is initially inserted in the left upper quadrant and replaced later with a robotic cannula (R1); the remaining two robotic ports (R2, R3) are located in the right abdomen, with a flexible liver retractor elevating segment 4 through the right anterior axillary line trocar (L). The camera port is the 12 mm epigastric trocar inserted to the right of the midline (C). The laparoscopic surgeon operates two assistant ports: a 5 mm trocar (A1) in the right lower quadrant, and a 15 mm trocar in the left lower quadrant (A2) typically inserted through GelPOINT access device for specimen extraction. The LigaSure is operated from (A2).

Peritoneal entry is achieved with a 5 mm optical separator in the left subcostal region. This later becomes a robotic trocar (R1). A 12 mm camera port is inserted 2–3 cm to the right of the midline superior to the umbilicus to expose the lateral border of the portal vein and uncinate process (C). Two 5 mm ports in the right upper abdomen quadrant are eventually converted to 8 mm robotic trocars (R2 and R3). The liver retractor is inserted through a 5 mm port in the right anterior axillary line (L). Assistant ports (A1 and A2) are placed in the right and left lower quadrants. A GelPOINT device (Applied Medical, Rancho Santa Margarita, California) is used to seal a 6 cm incision made either in the left lower quadrant or upper midline for the extraction of the pancreatic head (A2), as well as to provide ready access for sponges and the passage of needles and staplers.

STEPWISE SURGICAL TECHNIQUE

Like open surgery, the robotic technique uses four-handed cooperation to expose critical structures that may be distorted by tumor, obesity, and/or pancreatitis. Avoiding and safely controlling hemorrhage from major vessels require strong familiarity with the anatomy as well as skilled collaboration between the laparoscopic and console surgeons.

Step 1: Mobilization of the Right Colon and Pancreatic Head

Gravity is used to retract the hollow viscera during the laparoscopic phase, during which we use a 45° angled laparoscope, atraumatic graspers, suction, and the LigaSure (Covidien, Boulder, Colorado) (**Figures 78.3a and b**). The right colon is mobilized to expose the duodenum crossing beneath the mesenteric vessels. The pancreatic head is elevated from the retroperitoneum (Kocher maneuver) (**Figure 78.3a**) up to the origin of the superior mesenteric artery (SMA), and the ligament of Treitz is divided from the right beneath the mesenteric vessels whenever possible. The extent of the peritoneal reflection along the proximal jejunum may require mobilizing the proximal jejunum in the inframesocolic compartment. After the mesentery of the proximal jejunum is divided, the pancreatobiliary limb is measured, and the site of the future duodenojejunostomy is located approximately 50–60 cm downstream by tacking the jejunum to the stomach in the correct orientation (**Figure 78.3b**) with an EndoStitch (Covidien, Boulder, Colorado).

Step 2: Docking the Robot

After mobilizing the pancreatic head and dividing the jejunum, the robot (Intuitive Surgical, Sunnyvale, California) is used for the portal dissection and subsequent reconstruction. The robot is docked directly over the patient's head with arms 2 and 3 on the patient's right, ensuring that the liver retractor does not conflict with the inferior robotic arm.

Step 3: Dissection of the Porta Hepatis

With the robot in position, antegrade cholecystectomy may first be required to remove a dilated gallbladder, which prevents dissection of the portal structures. The common hepatic artery (CHA) lymph node is then mobilized and

resected to expose the superior border of the pancreas, the CHA, and the gastroduodenal artery (GDA) origin (**Figure 78.4**). The right gastric artery is identified and divided to complete the mobilization of the duodenum. The origin of the GDA is cleared of surrounding tissue and temporarily occluded to confirm inflow from the CHA (either visible pulsation or laparoscopic B-D mode ultrasound captured in the patient console). The GDA is ligated proximally with a 2–0 silk tie and divided with a vascular load of the stapler (**Figure 78.4a**). With the GDA divided and the CHA in view, the proximal duodenum is cleared of the right gastroepiploic arcade and prepyloric lymph nodes and divided with a linear cutting stapler (**Figure 78.4b**). The gastroepiploic pedicle is divided with a vascular stapler, preserving the vessels along the greater curve of the stomach but keeping the prepyloric lymph nodes in continuity with the specimen. With the duodenum out of the way, the common bile duct is elevated to expose the PV and encircled with a vessel loop. The portal lymph nodes are swept away from the hepatic arteries and bile duct and into the specimen. The lateral margin of the bile duct is inspected to identify a replaced right hepatic artery. The bile duct is divided with a stapler to prevent a bile leak, which will obscure the operative field during dissection along the SMA. The distal bile margin is sampled for frozen section.

Step 4: Mobilization of the Superior Mesenteric Vein and Division of the Pancreatic Neck

With the portal dissection complete, the inferior border of the pancreas is cleared of overlying areolar tissue to expose the superior mesenteric vein (SMV). Robotic scissors dissect the SMV-portal vein away from the posterior surface of the pancreas under direct vision. An articulated grasper is used to pass an umbilical tape around the pancreatic neck to prevent venous injury during pancreatic transection (**Figure 78.5**). The transverse pancreatic arteries are suture ligated at the inferior and superior borders of the pancreas

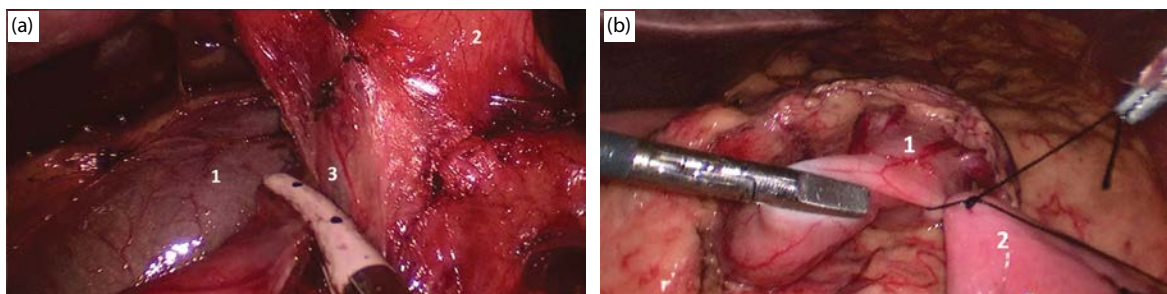


Figure 78.3 (a) Kocher maneuver. Reflection of the duodenum and pancreatic head from the retroperitoneum with dissection of the adventitia surrounding the SMA to expose the inferior vena cava and the aorta. 1: Inferior vena cava. 2: Rejected duodenum and pancreatic head. 3: Common bile duct lymph node. (b) Preliminary creation of the duodenojejunostomy. The jejunum is marked with sutures to locate the future duodenostomy 40 cm downstream from the bilioenteric anastomosis. The jejunum is marked in the correct orientation and tacked to the stomach to maintain its correct orientation after docking the robot. 1: Stomach. 2: Jejunum.

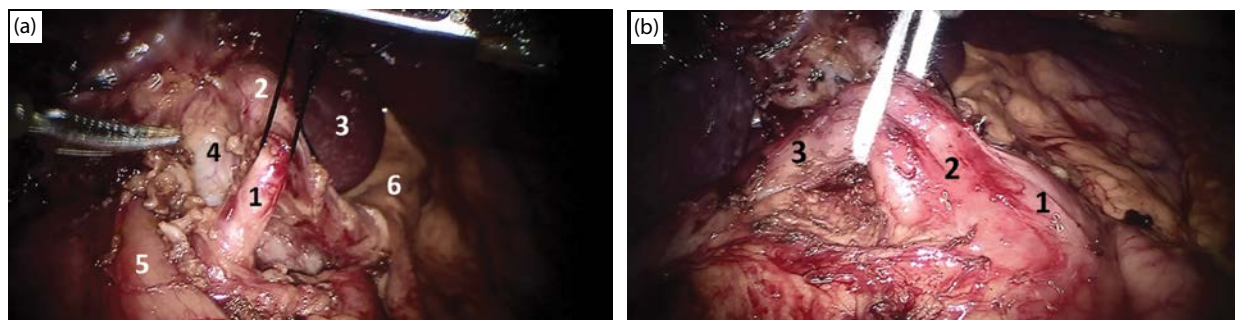


Figure 78.4 (a) Ligation of the gastroduodenal artery. 1: Gastroduodenal artery. 2: Right hepatic artery. 3: Caudate lobe of the liver. 4: Portal vein. 5: Duodenum. 6: Common hepatic artery. (b) Transection of the first portion of the duodenum for pylorus-preserving pancreaticoduodenectomy. 1: Antrum of the stomach. 2: Pylorus. 3: First portion of the duodenum.

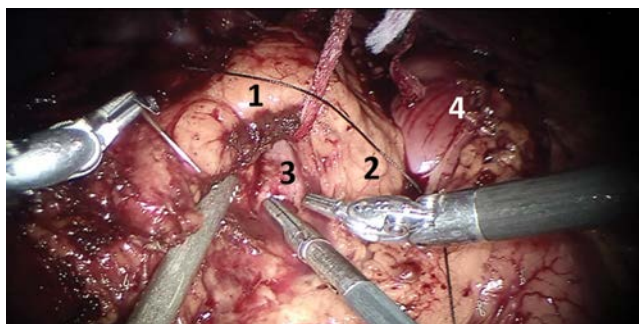


Figure 78.5 Division of the pancreatic neck. An umbilical tape is used to maintain venous exposure during transection. 1: Pancreatic neck. 2: Pancreatic body. 3: Superior mesenteric vein. 4: Stomach.

using 2–0 silk. The pancreas is divided with cautery scissors. Cautery is not used to transect the pancreatic duct so that a frozen section can be accurately evaluated by pathology.

After the pancreas is divided, the SMV continues and is dissected free of overlying fat and small vessels proximally into the root of the small bowel mesentery. The origin of the right gastroepiploic vein is identified as it enters the SMV and is divided with a vascular stapler or 2–0 silk ties. The jejunum is divided to free the duodenal mesentery. The robotic Maryland dissector is used to ligate venous tributaries to the uncinate process using a combination of ties, LigaSure, or clips.

Step 5: Vascular Disconnection of the Pancreatic Head

The pancreas is elevated from the retroperitoneum with a “hanging maneuver” performed by the third robotic arm (R3) to rotate the SMA into view. Once the superior pancreaticoduodenal vein has been ligated, the only remaining structures are the arterial tributaries to the pancreas arising. The adventitia of the SMA is identified using the robotic Maryland dissector (Figure 78.6a). Retroperitoneal lymph nodes lateral to the SMA are divided using the LigaSure.

Tiny arterial branches are divided with the LigaSure device, whereas larger vessels are controlled proximally with a silk tie or clip and then transected distally with the LigaSure (Figure 78.6b). This exposure permits suture control of bleeding with 4–0 or 5–0 Prolene (Ethicon Endo-Surgery, Cincinnati, Ohio) using R1. The laparoscopic surgeon uses ports A1 and A2 to deploy the LigaSure and clear the field of blood with suction. The specimen is placed within a large specimen bag and extracted through the GelPOINT. The retroperitoneal margin is irrigated and inspected for bleeding. Gold fiducials are placed in cases of suspected or known malignancy.

Step 6: Restoration of Gastrointestinal Continuity

Restoring GI continuity reproduces the open technique with the sole substitution of multifilament absorbable 5–0 suture. The proximal jejunum is inspected to be sure there has been no inadvertent devascularization during division of the duodenal mesentery. The pancreaticobiliary limb is pulled beneath the vessels and the degree of tension evaluated prior to creating the pancreatic anastomosis. A two-layer, end-to-side, duct-to-mucosa pancreaticojejunostomy (Figure 78.7a) is performed using a modified Blumgart technique. Transpancreatic 2–0 silk horizontal mattress sutures are used to anchor the seromuscular layer of the jejunum to the pancreatic parenchyma while preventing potential parenchymal tears. Interrupted sutures (5–0 Vicryl) are placed around the pancreatic duct to maximize visualization during subsequent creation of the anastomosis. A small jejunal enterotomy is made with cautery scissors, and an interrupted duct-to-mucosa anastomosis is completed in a parachute style. A pancreatic duct stent may be placed in small ducts to ensure duct patency (Figures 78.7a and b). The anastomosis is completed with an anterior layer of 2–0 silk sutures using the needles left in place from the posterior row.

Next, the stapled end of the bile duct is resected. A single-layer end-to-side hepaticojejunostomy (Figure 78.7c) is created with interrupted 5–0 Vicryl in the case of a small duct. A running technique employing 4–0 V-Loc (Covidien,

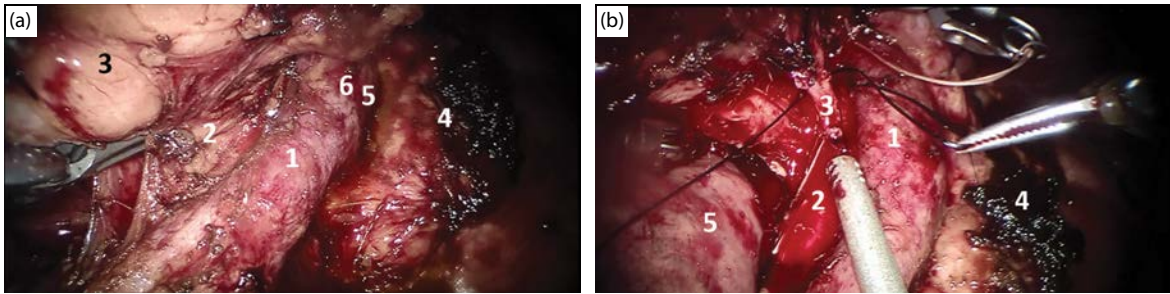


Figure 78.6 (a) Dissection of the adventitia to expose the SMA. Once the pancreatic neck is transected, the superior mesenteric vein is exposed and venous tributaries ligated and divided to expose the superior mesenteric artery. 1: SMV. 2: Adventitia surrounding the SMA. 3: Head of the pancreas. 4: Neck of the pancreas. 5: Splenic vein traveling parallel and posterior to the tail of the pancreas. 6: Confluence of the SMV and SV to form the portal vein. (b) Division of the SMA arterial tributaries to the pancreatic head. 1: Portal vein. 2: SMA. 3: Tributary of the SMA to the pancreatic head. 4: Distal pancreas. 5: Mobilized duodenum. Note the vascular bulldog clamp in position on a large superior pancreaticoduodenal vein branch.

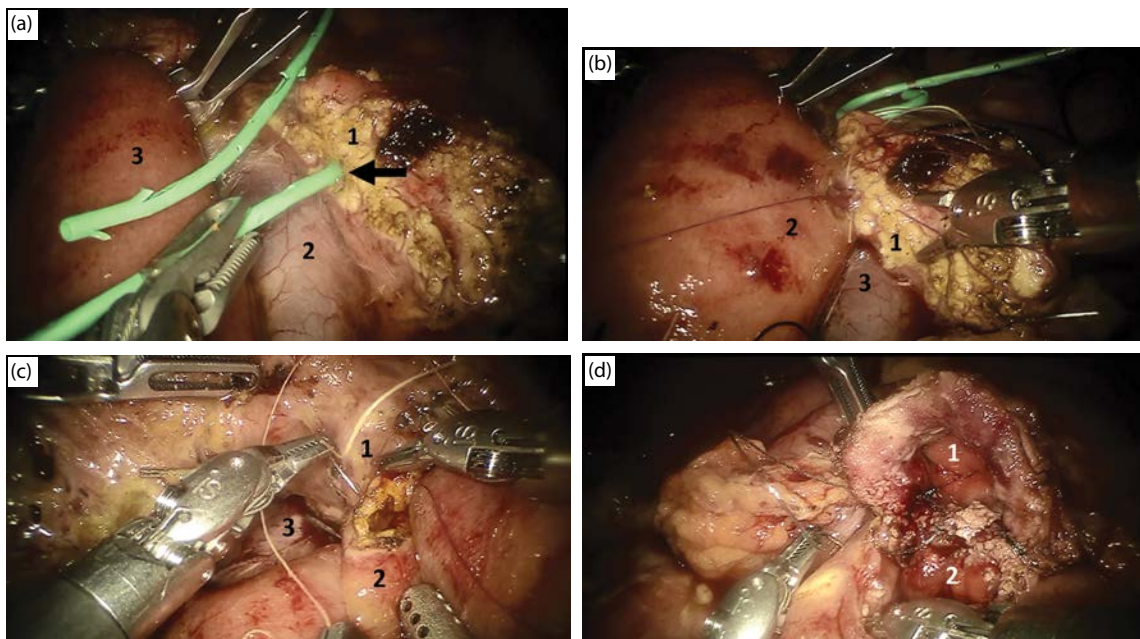


Figure 78.7 (a) Cannulation of the pancreatic duct. 1: Pancreatic remnant and cannulated pancreatic duct (arrow). 2: Portal vein. 3: Loop of jejunum for pancreaticojejunal anastomosis. (b) Duct to mucosa pancreaticojejunostomy. The pancreas and the jejunum are approximated above the portal vein. The previously cannulated duct is anastomosed to the intestinal mucosa. 1: Pancreatic tail. 2: Jejunum, biliary limb. 3: Portal vein. (c) End-to-side hepaticojejunostomy. The end of the hepatic duct is anastomosed to the lateral wall of the jejunum. 1: Hepatic duct. 2: Jejunum, biliary limb. 3: Foramen of Winslow and inferior vena cava. (d) Antecolic two-layer duodenojejunostomy. 1: Lumen of the first portion of the duodenum. 2: Lumen of the jejunum, alimentary limb.

Boulder, Colorado) is used for thick-walled ducts larger than 8 mm in diameter when visualization is optimal. Finally, an antecolic two-layer duodenojejunostomy is performed with a posterior layer of interrupted seromuscular 2-0 silk followed by full-thickness running 3-0 V-Loc after the duodenum and jejunum are opened (**Figure 78.7d**). The status of the duodenal mucosa is checked to ensure viability. A Connell technique is used to complete the anterior wall of the anastomosis, after which an anterior row of seromuscular sutures is placed.

In patients with fragile nutritional status, a transgastric feeding jejunostomy tube is placed using a standard Stamm technique. After hemostasis is ensured, and all surgical foreign bodies are accounted for, two round 19F surgical drains are placed—one anterior and one posterior to the biliary and pancreatic anastomoses. The robot is undocked, and the GelPOINT site and other ports are closed. The skin is closed with a monofilament subcuticular closure followed by sterile dressings. The patient is awakened, extubated, and transferred to the recovery room for overnight observation.

LIMITATIONS OF CURRENT TECHNOLOGY

Time-tested techniques for open pancreatic resection can be implemented in a minimally invasive fashion with the assistance of robotic technology. However, current platforms have several important limitations, the most significant of which is the inability to operate in multiple quadrants of the abdomen. This limitation is compounded by the inability to change the position of the table once the robot is docked, meaning that gravity cannot always be used effectively as a retractor of the viscera. The size and location of current robotic arms limit their freedom of motion and degrade the enormous potential of robotic assistance. Trocar placement is critical to minimize interference between the arms and conflicts with the laparoscopic surgeon seated at the bedside. The lack of tactile feedback prolongs the learning curve and may lead to excess tension and crushing of tissues. Compensating for the lack of tactile feedback requires subtle visual clues reflecting tension on tissue, blood vessels, and fine suture material. This skill requires a significant learning curve and is rapidly

perishable without ongoing practice. Finally, exchanging surgical instruments is a cumbersome process that disrupts the flow of the operation and prolongs the operating time.

POTENTIAL ADVANTAGES OF MINIMALLY INVASIVE PANCREATODUODENECTOMY

PD is one of the most complex procedures in abdominal surgery. PD requires wide exposure of structures, gentle dissection and manipulation of vasculature, and thorough knowledge of the anatomy to reconstruct the biliopancreatodigestive tract. Given its high complexity and steep learning curve, robot-assisted pancreatoduodenectomy (RAPD) has been adopted at a slow pace by selected centers despite the popularity of minimal access techniques for other operative procedures.

Retrospective outcomes of open pancreatoduodenectomy (OPD), laparoscopic pancreatoduodenectomy (LPD), and RAPD are shown in [Table 78.1](#). At this early stage of widespread adoption, RAPD requires a longer operative

Table 78.1 Blood loss, operative time, and conversion rates for pancreatoduodenectomy in the literature

Study	Type of study	Type of procedure	Operative blood loss (mL) ^a	Operative time (hours) ^a	Conversion rate (%)
Literature reviews					
Gagner and Palermo ¹³	Literature review	LPD (<i>n</i> = 146)	142.8	7.3	46
Strijker et al. ⁸	Literature review	RAPD (<i>n</i> = 131)	440	8.5	16.4
Noncomparative studies					
Winter et al. ¹¹	Retrospective, single center	OPD (<i>n</i> = 1423)	Median: 800	Median: 6.3	NA
Cameron et al. ¹⁰	Retrospective, single center	OPD (<i>n</i> = 1000)	Median: 1090 (in 1970s) and 700 (in 2000s)	Median: 8.8 (in 1970s) and 5.5 (in 2000s)	NA
Giulianotti et al. ⁷	Retrospective, two centers	RAPD (<i>n</i> = 50)	394	7	18.3
Boggi et al. ¹⁴	Prospective cohort	RAPD (<i>n</i> = 34)	220	10	0
Boone et al. ⁹	Retrospective, single center	RAPD (<i>n</i> = 200)	Median: 250	Mean: 8	6.5
Comparative studies					
Buchs et al. ¹⁵	Prospective cohort	RAPD (<i>n</i> = 44) OPD (<i>n</i> = 39)	387 (RAPD) versus 827 (OPD); <i>p</i> = 0.0001	7.4 (RAPD) versus 9.3 (OPD); <i>p</i> = 0.0001	4.5
Lai et al. ¹²	Retrospective	RAPD (<i>n</i> = 20) OPD (<i>n</i> = 67)	Median: 247 (RAPD) versus 774.8 (OPD); <i>p</i> = 0.03	8.2 (RAPD) versus 4.4 (OPD); <i>p</i> = 0.01	5
Bao et al. ¹⁶	Retrospective	RAPD (<i>n</i> = 28) OPD (<i>n</i> = 28)	Median: 100 (RAPD) versus 300 (OPD); <i>p</i> = 0.0001	Median: 7.2 (RAPD) versus 6.8 (OPD); <i>p</i> = 0.04	14
Chen et al. ⁶	Prospective	RAPD (<i>n</i> = 60) OPD (<i>n</i> = 120)	Median: 400 (RAPD) versus 500 (OPD); <i>p</i> = 0.005	Median: 6.8 (RAPD) versus 5.4 (OPD); <i>p</i> = 0.001	1.7

Notes: LPD, laparoscopic pancreatoduodenectomy; OPD, open pancreatoduodenectomy; RAPD, robot-assisted pancreatoduodenectomy. See the reference number in the first column.

^a Mean operative blood loss and mean operative time are depicted unless otherwise specified.

time than OPD. However, as expertise is achieved, the differences tend to disappear or become clinically insignificant. Conversion rates during RAPD vary between 0% and 35%, with lower conversion rates achieved as expertise is acquired (Table 78.1). A prospective matched series found longer mean operative times in the RAPD group when compared to OPD (410 ± 103 versus 323 ± 80 minutes; $p = 0.001$), however, when comparing the last cases of both cohorts, no differences in the mean operative times were found (340 [98] versus 324 [92] minutes; $p = 0.981$).¹ Similarly, overall median blood loss was lower in the RAPD group when compared to OPD (400 versus 500 mL; $p = 0.005$), differences which became more distinct among the latest robot-assisted cases due to technical refinements resulting from the learning curve: 200 mL (IQR 100 – 450 mL) for RAPD and 500 mL (IQR 300 – 700) for OPD ($p = 0.002$).³ Reported blood loss during RAPD ranges from a low of 250 mL to a high of 500 – 600 mL, which compares favorably with reported open series.

Postoperative complications

Complication rates after RAPD are similar to those of OPD (38%–41%) and LPD (16%–37%) at expert centers. Major complication rates, defined as Clavien-Dindo classification ≥ 3 , have been reported in the 15%–26% range. The most common complications are pancreatic fistula, delayed gastric emptying, bile leak, gastrointestinal anastomotic leak, intra-abdominal bleeding, intraperitoneal fluid collection, and afferent loop obstruction.¹ Surgical site infection is more common in the open group (1.7% versus 12.5%; $p = 0.033$). Pancreatic fistula incidence has been reported between 13.3% and 35%, but a recent study by Boone et al. shows a grade B/C pancreatic fistula rate of 6.9% in a high-volume center. No significant differences between RAPD and OPD have been observed in postoperative complications, pancreatic fistulae, bleeding, reoperation, biliary leaks, or delayed gastric emptying. Reoperation rates after RAPD are 3.3%–4% and similar to OPD. Reports on perioperative mortality rate for RAPD range between 1.7% and 3.3% as previously reported for the open and laparoscopic approaches (1.3%–2.5%).

Oncologic outcomes

Margin negative resection rates after RAPD for cancer range between 79% and 100%, while the number of lymph nodes harvested ranges between 14 and 32. Several studies have compared resection margins and node harvest after RAPD and OPD without finding inferiority. No port-site recurrences have been reported in the literature. Survival is no different after RAPD than OPD.¹

The learning curve

A recent retrospective review of 200 RAPD performed in a high-volume institution demonstrated a three-phase

model of improvement in operating time.³ Mean operative time was 581 ± 81 minutes for the first 80 procedures; 444 ± 73 minutes between cases 81 and 140, and 390 ± 75 minutes for cases 141–200. This 33% improvement in operative time was achieved over 6 years as compared to OPD series showing a similar decrease in operative time (37%) achieved over three decades (from 528 minutes in the 1970s to 330 minutes in the 2000s).³ Similar reductions in blood loss after RAPD and OPD were observed.¹ The conversion rate decreased 10-fold at case 20 (35.0% versus 3.3%; $p < 0.001$), and the pancreatic fistula rate fell from 27.5% to 14.4% after 40 cases ($p = 0.04$). The authors concluded that 20 procedures are necessary for early optimization as measured by blood loss and conversion rate. Eighty procedures constitute the learning curve for overall efficiency as measured by operative time.

SUMMARY

Robotic pancreaticoduodenectomy allows authentic recreation of time-tested open surgical procedures with minimal access techniques. Preliminary results on length of stay, early postoperative complications, and oncologic efficiency are comparable to open surgery, albeit after a prolonged learning curve to achieve technical proficiency. Technological innovation and increased surgeon familiarity over time will lead to greater adoption and acceptance of novel methods to learn complex surgical reconstruction using minimal access techniques.

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Laparoscopic pancreaticoduodenectomy (Whipple)

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INTRODUCTION

Minimally invasive surgery has had a tremendous impact on hepatopancreaticobiliary surgery in the last three decades. The use of laparoscopic cholecystectomy for the treatment of biliary disease has been the greatest example of this influence. While minimally invasive techniques aim to enhance recovery by decreasing abdominal wall trauma and postoperative pain, this benefit may not be as pronounced in pancreatic surgery, where the consequences of pancreatic removal and subsequent reconstruction far outweigh these factors. The goal of minimally invasive pancreatic surgery is not only to decrease pain but also to improve the operation overall by decreasing blood loss, increasing lymph node harvest, and reducing recovery times. While laparoscopic distal pancreatectomy has been proven to have advantages over its open counterpart and has gained widespread acceptance, the same is not true for a laparoscopic pancreaticoduodenectomy (LPD). The location of the pancreas in the retroperitoneum in close proximity of mesenteric vasculature makes dissection hazardous, and the bilio-pancreatic reconstruction is challenging, requiring advanced laparoscopic skills and additional time. As expected, the learning curve for LPD is steep, which also limits the widespread adoption of this technique. It is usually beneficial for surgeons early in the learning curve to operate on early neoplastic or benign disease when resection of the head is associated with less inflammatory reaction. Unfortunately, these patients usually have nondilated bile and pancreatic ducts, which makes the reconstruction more challenging. Vascular involvement continues to be an issue, and patients who require a vascular control or reconstruction may require conversion to open pancreaticoduodenectomy (OPD). LPD is associated with longer operative times and is more resource intensive than OPD; therefore, at this current time, LPD remains confined to a small number of high-volume centers.

OUTCOMES OF LAPAROSCOPIC PANCREATICODUODENECTOMY

Palanivelu et al.¹ from India presented the first series favoring LPD in 2007. Forty-five patients treated with LPD had a mean hospital stay of 10.2 days, operating time of 370 minutes, and an average of 13 lymph nodes harvested without any conversions to open. Morbidity was 26.6%, mortality of 2.2%, with a median survival of 49 months. They published a follow-up study of 75 patients in 2009 confirming the oncologic efficacy of LPD.¹ We compared 215 patients treated with OPD and 53 who underwent LPD. In terms of the results of morbidity, mortality, postoperative pancreatic fistula (POPF), rate of reoperation, and oncological results, there were no statistically significant differences. LPD patients had a hospital stay of 8 days, 1.1 days in the intensive care unit, longer surgery time, less blood loss, and a greater number of lymph nodes harvested with an average of 23.4 nodes. All of these variables represented a statistically significant difference.^{2,3}

One of the advantages of laparoscopy is decreased length of stay (LOS), which is directly proportional in the case of LPD to the presence or absence of complications and POPF. In a large series reporting more than 30 cases, the overall complications range from 26.8% to 74% with major complications (Clavien-Dindo ≥ 3) ranging between 5.6% and 28%. Reported rates of POPF grade B–C range between 6.3% and 44%.^{3–10} Six meta-analyses are currently available in the literature comparing LPD with OPD ([Table 79.1](#)).^{11–16} LPD was associated with reduced blood loss, shorter hospital stay, but longer operative times. Mortality, morbidity, and POPF rates were similar to OPD as in our series.

While technically feasible, the oncologic efficacy of a laparoscopic LPD continues to be in question. In one of the largest experiences so far, Croome et al. compared 322

Table 79.1 Meta-analyses comparing open and minimally invasive pancreaticoduodenectomy

Reference/Number of studies	Number of patients (Open/MIS PD)	EBL	Operative time	POPF/Overall complications	LOS	Margins	Nodes	Conclusions
Correa-Gallego et al. ¹¹ (6)	373/169	Less with MIS PD WMD 1460 mL $p < 0.001$	Longer with MIS PD WMD 131 minutes $p = 0.003$	No significant difference POPF 21% MIS versus 17% OPD $p = 0.94/0.15$	Shorter with MIS PD 3.7 days less $p = 0.02$	Lower R1 margins for MIS PD $p = 0.007$	Increased lymph node harvest for MIS PD; 3 nodes more $p = 0.03$	MIS PD is feasible, associated with improved outcomes, but superiority cannot be confirmed without randomized controlled trials
Nigri et al. ¹⁴ (8)	419/204	Less with MIS PD $p < 0.0001$	Longer with MIS PD $p < 0.0001$	No significant difference $p = 0.80/0.34$	Shorter with MIS PD $p = 0.0497$	Lower R1 margins for MIS PD $p = 0.90$	Increased lymph node harvest for MIS PD $p = 0.050$	MIS PD is safe and feasible in expert hands, may reduce overall complications similar POPF, DGE
Qin et al. ¹² (11)	542/327	Less with MIS PD MD -362 mL $p < 0.001$	Longer with MIS PD MD 105 minutes $p < 0.001$	No significant difference $p = 0.86/0.05$	Shorter with MIS PD 2.6 days less $p = 0.001$	Similar R0 margins $p = 0.07$	Similar lymph node harvest $p = 0.48$	MIS PD associated with some advantages, should be performed in high-volume institute in patient with minimal pancreatitis and small cancers
Lei et al. ¹³ (9)	429/209	Less with MIS PD WMD -406 mL $p = 0.007$	Longer with MIS PD WMD 107 minutes $p = 0.007$	No significant difference $p = 0.78/0.16$	Shorter with MIS PD WMD -4.14 days $p = 0.02$	Lower R1 margins for MIS PD $p = 0.03$	Similar lymph node harvest $p = 0.11$	MIS PD is feasible, likely with improved outcomes; selection bias had minimal effect on final outcomes
Zhang et al. ¹⁵ (22)	5102/1018	Less with MIS PD WMD -160 mL $p < 0.001$	Longer with MIS PD WMD 84 minutes $p < 0.001$	No significant difference $p = 0.17/0.83$	Shorter with MIS PD WMD -3.57 days $p < 0.001$	Lower R1 margins for MIS PD $p = 0.005$	Increased lymph node harvest for MIS PD WMD 1.74 nodes $p < 0.001$	MIS PD a reasonable alternative to OPD with potential advantages
de Rooij et al. ¹⁶ (22)	26,131/2759	Less with MIS PD WMD -385 mL $p = 0.001$	Longer with MIS PD WMD 73.5 minutes $p = 0.001$	No significant difference $p = 0.0009$	Shorter with MIS PD WMD -3.1 days $p < 0.0001$	Lower R1 margins for MIS PD $p = 0.04$	Similar lymph node harvest $p = 0.76$	MIS PD with some advantages, should be practiced in high-volume centers with a structured training program

Notes: EBL, estimated blood loss; LOS, length of stay; MD, mean difference; MIS PD, minimally invasive pancreaticoduodenectomy; POPF, postoperative pancreatic fistula; WMD, weighted mean difference.

patients who underwent open ($n = 214$) and laparoscopic ($n = 108$) PD. Both groups were similar in tumor size, neoadjuvant therapy, node positivity, and resection margin status. While the overall survival was similar in the two groups, there was an increased risk of local recurrence following the open approach versus laparoscopy (27% versus 15%, $p = 0.04$). Time to receive chemotherapy was longer in OPD (59 versus 48 days, $p = 0.001$). A greater delay in chemotherapy beyond 8 weeks was also observed with OPD (41% versus 27%, $p = 0.01$). In addition, the likelihood of delay in chemotherapy beyond 3 months or not receiving it at all due to postoperative complications was greater with the open group than with the laparoscopic group (12% versus PD 5%, $p = 0.04$).⁵

Liao et al. recently reviewed over a thousand patients who underwent a LPD or a robotic pancreaticoduodenectomy (RPD). They report a POPF rate and overall morbidity of 17% and 35.9%, respectively. On average, 17.1 nodes were harvested; R0 resection was successfully performed in 91.6% of the patients, and the mortality was 2.2%. They concluded from their meta-analysis that minimally invasive pancreaticoduodenectomy (MIS PD) is feasible and safe in appropriately selected patients.¹⁷

SURGICAL TECHNIQUE

LPD is a complex undertaking that requires an incorporation of resources, surgical skills, and precise technique, which is based on correct identification of dissection planes, meticulous hemostasis, judicious handling of vasculature, performing a wide lymphadenectomy, and avoiding contamination. The patient is placed supine in a split leg position after being carefully secured to the table. A central venous catheter is placed selectively in a patient who may need closer monitoring of hemodynamic status. A diagnostic laparoscopy is performed, but in our experience it is uncommon to find metastatic disease that was not diagnosed on imaging preoperatively. A six trocar approach is favored, with the trocars placed in a semicircle around the head of the pancreas (Figure 79.1). The Hasson trocar is placed about 16 cm from the xiphoid process and pneumoperitoneum obtained. Preferably three more 10–12 mm trocars are placed to allow passage of camera, linear staplers, or other larger instruments depending on the stage of resection or reconstruction.

RESECTION

Division of omentum: The greater omentum is split longitudinally using an ultrasonic dissector to prepare for eventual antecolic duodenojejunostomy. The ligament of Treitz is exposed and can be partially or fully dissected at this point. The lesser sac is then entered by dividing the gastrocolic ligament completely, avoiding injury to the gastroepiploic vessels.

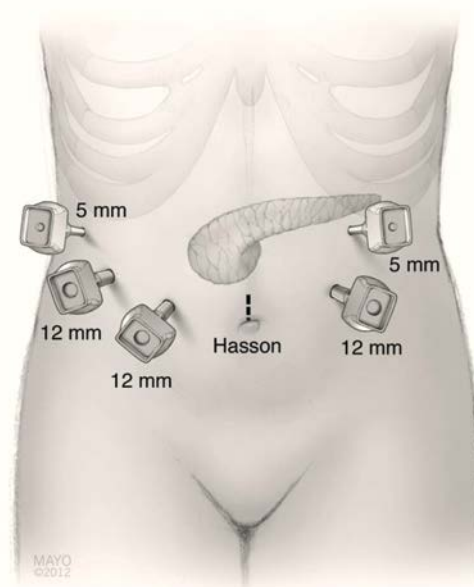


Figure 79.1 Trocar placement.

Mobilization of the colon

The right gastroepiploic vessels and the branches of the trunk of Henle are identified. The colon is then mobilized from left to right including the hepatic flexure and the right side of the colon as necessary to expose the head of the pancreas. This part of the surgery is well suited to laparoscopy, as it avoids a larger incision that is usually needed, especially in obese patients.

Division of proximal bowel

The gastroepiploic vessels are divided using a laparoscopic linear vascular stapler. The first part of the duodenum is mobilized and transected 2–3 cm distal to the pylorus using a similar stapler. There are numerous small vessels emanating from the head to the first portion of the duodenum, which have to be controlled in an effort to avoid bleeding, which obscures the view. Magnification afforded by the laparoscope allows precise control of these vessels even when there may be significant inflammation.

Division of gastroduodenal artery

Attention is now turned to the hilar structures. The peritoneum over the hepatoduodenal ligament is divided with an ultrasonic coagulator and the hepatic artery and gastroduodenal artery (GDA) are exposed which is facilitated by the excision of lymph node station 8a. We prefer to divide the GDA with a vascular stapler, but clips or sutures can be utilized as well.

Division of common bile duct

The CBD is skeletonized circumferentially and divided sharply. The posterior wall of the CBD is left slightly longer to facilitate the later anastomosis. A bulldog clamp is placed proximally on the CBD to prevent spillage of bile and a portion of the cut edge is sent for frozen section to ensure a negative margin.

Retropancreatic window

The inferior aspect of the pancreas is retracted cephalad while applying gentle downward traction on the transverse mesocolon. This exposes the avascular plane between the pancreatic neck and superior mesenteric vein (SMV). This space is dissected bluntly to create a window under the neck of the pancreas, which is encircled with a Penrose drain ([Figure 79.2](#)). A large right angle band passer is utilized for this dissection.

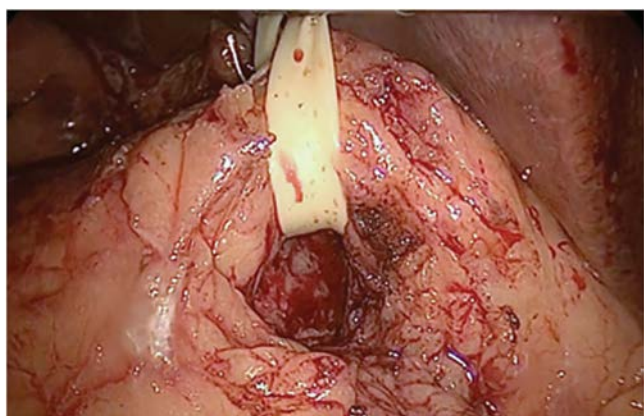


Figure 79.2 Penrose around the neck of the pancreas. (Courtesy of Dr. Horacio J. Asbun.)

Kocher maneuver and division of ligament of Treitz

With the surgeon standing on the right, a wide Kocher maneuver is performed. The inferior vena cava is exposed and the duodenum, head of the pancreas, and uncinate process are mobilized completely from the retroperitoneum and reflected medially. This includes the retropancreatic and retrocholedochal nodes and often exposes the left renal vein and superior mesenteric artery (SMA). The ligament of Treitz is then mobilized from the right side using a harmonic coagulator. It is uncommon to require exposure of the inferior mesenteric vein unless there are significant adhesions around the ligament of Treitz. The jejunum is divided with an endoscopic stapler, and circumferential dissection allows it to be delivered to the supramesocolic compartment.

Pancreatic transection

Transection of the pancreas is usually performed with ultrasonic shears. The pancreatic duct once identified is transected with a scissor 2–3 mm to the right of the parenchyma to leave a stump and facilitate eventual duct to mucosa-type anastomosis ([Figure 79.3](#)). The distal end of the duct can be stented for later identification.

Dissection of uncinate process and superior mesenteric artery

The uncinate process is retracted to the right while the assistant is retracting the SMV to the left using laparoscopic kittner. The vessels are controlled with vessel loops should a vein resection be required. Small vessels from the SMV are clipped to dissect free the uncinate process. SMA, which usually lies inferomedial to the SMV, is separated from the uncinate process using a vessel sealing device. The inferior pancreaticoduodenal artery is controlled with a bipolar device

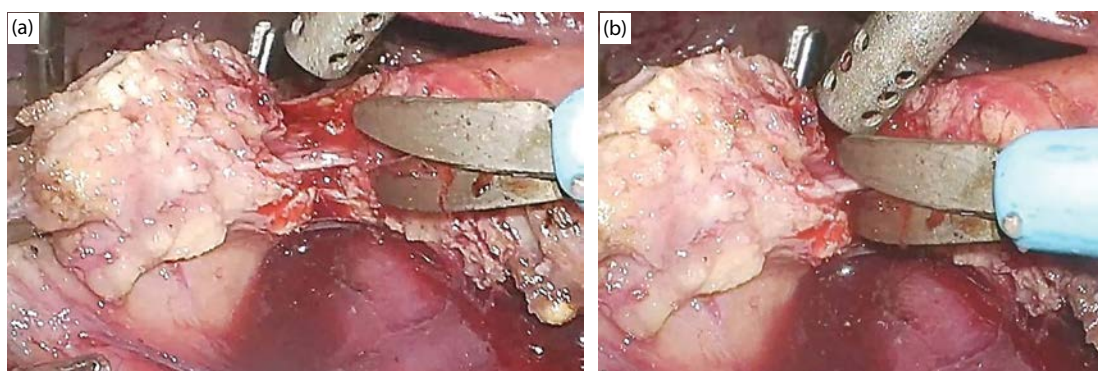


Figure 79.3 (a) Pancreatic duct exposure; (b) Sharp transection 5 mm to the right of the body of the pancreas. (With permission from Dr. Horacio J. Asbun.)

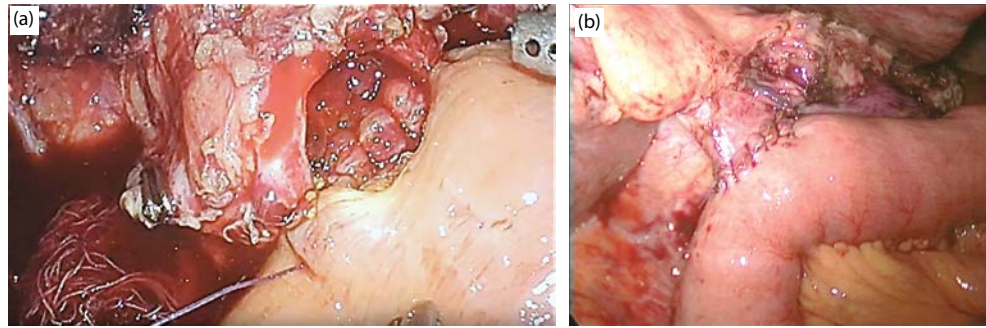


Figure 79.4 (a) Posterior layer of choledochojejunostomy; (b) Completed choledochojejunostomy. (Courtesy of Dr. Horacio J. Asbun.)

or clipped if large in caliber. The SMA is identified, and a complete neurovascular clearance of the lateral tissue with a nodal dissection is performed under magnified vision using a combination of energy device, clips, or sutures as needed.

Vascular reconstruction

If vein resection is required, the portal confluence has to be completely exposed including the splenic vein. Heparin is administered prior to clamping the vein, which is then resected *en bloc* with the PD specimen. Venous continuity is reestablished with either a patch or an interposition polytetrafluoroethylene graft in an end-to-end fashion using 6–0 Prolene suture as appropriate.

Specimen retrieval

The specimen is placed in an EndoCatch bag via the Hasson trocar and removed by enlarging the trocar site. In our practice, the surgeon takes the specimen to pathology for evaluation of the margins, ensuring the adequacy of resection. While the margins are being assessed, the assistant proceeds with the cholecystectomy in the standard fashion. Subsequently, the fascia is reapproximated with

monofilament absorbable sutures, and pneumoperitoneum is reestablished in preparation for reconstruction.

RECONSTRUCTION

Hepaticojejunostomy

Reconstruction commences by performing an end-to-side hepaticojejunostomy. The surgeon moves to the right side of the table for this part of the procedure. A 4–0 or 5–0 absorbable suture on an RB1 needle is used. Usually a running stitch is used to anastomose the posterior wall of the duct to the jejunum; alternatively, interrupted stitches can be used but are utilized infrequently (**Figure 79.4**). The anterior wall is reconstructed in a similar fashion, and the sutures are tied on the right side.

Pancreaticojejunostomy

The surgeon moves back between the legs for this part of the reconstruction. A posterior outer layer of the anastomosis is first created between the posterior aspect of the pancreas and the seromuscular layer of the jejunum using a running 4–0 or 5–0, nonabsorbable, monofilament suture on a RB1 needle (**Figure 79.5**). Ultrasonic shears are then used to

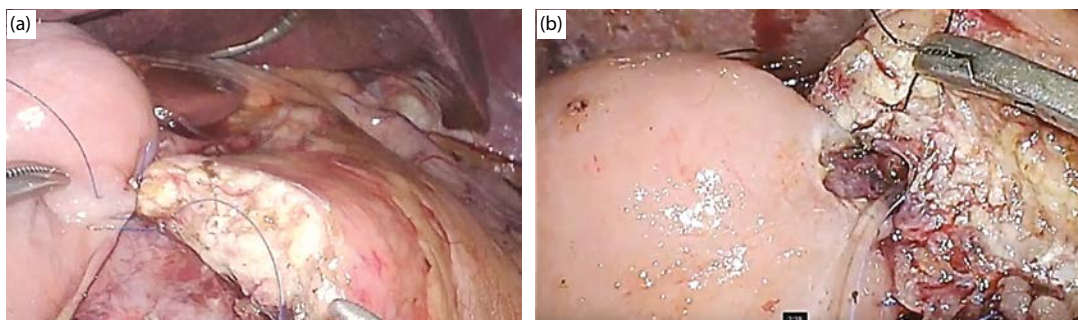


Figure 79.5 (a) Posterior layer of pancreaticojejunostomy; (b) Posterior layer of duct to mucosa anastomosis. (Courtesy of Dr. Horacio J. Asbun.)

create an enterotomy in the jejunum slightly larger than the pancreatic duct. A duct-to-mucosa anastomosis is created by first placing a center stitch at 6 o'clock using an absorbable 5–0 suture on a TF needle. This first stitch is left untied and used for retraction. Usually six stitches are needed depending on the size of the duct. Another stitch is placed cephalad, which is tied, and another caudad thus completing the posterior layer. The anterior layer is performed in a similar fashion, and all the stitches are tied at the end. Caution has to be advocated at this juncture to ensure the sutures do not cross, as detangling can be laborious. Caution also has to be advised when placing the outer layer of sutures on a soft pancreas.

Duodenojejunostomy

An antecolic end-to-side duodenojejunostomy is performed in the last anastomosis, which is performed in two layers. Absorbable 3–0 running suture is used for all the layers, with the outer layers being seromuscular.

A 15-French round drain is placed behind the pancreaticojejunostomy and hepaticojejunostomy. The midline fascia is reapproximated with preplaced monofilament absorbable suture. Generally, a nasogastric tube is not utilized, and the patient is started on a liquid diet within 1–3 days. We routinely check the drain amylase prior to removal to ensure there is no leak.

CONCLUSION

Laparoscopic pancreaticoduodenectomy has and will continue to test the technical skills of a surgeon at the highest

level. While level I evidence is lacking, we have enough data to support its noninferiority compared to the open approach. It may offer some advantages in terms of length of hospitalization, blood loss, node harvest, and time to chemotherapy. The advent of advanced robotics may offset some of the technical challenges of the procedures and broaden its appeal.

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Laparoscopic distal pancreatectomy

OMAR YUSEF KUDSI, LERNA OZCAN, AND MICHEL GAGNER

INTRODUCTION

Mishandling the pancreas through laparoscopic or robotic instrumentation can be unforgiving and may result in iatrogenic injury that may increase the risk of complications, such as pancreatic fistula. A minimally invasive approach for benign and malignant lesions in the tail of the pancreas is gaining favor among surgeons. Laparoscopic distal pancreatectomy (LDP) has smaller incisions leading to faster patient recovery and shorter hospital stays when compared to open distal pancreatectomy (ODP). Multiple studies have demonstrated that these added benefits do not compromise the oncologic outcomes. These oncologic outcomes are even similar when comparing LDP to robotic distal pancreatectomy (RDP).

PREOPERATIVE WORKUP

The use of a pancreatic protocol computed tomography (CT) scan has limited the need for staging laparoscopy. Intraoperative ultrasonography in experienced hands may assess vascular tumor involvement and possible respectability as well as aid in intraoperative tumor localization, but no comparative data exist to describe the advantages of this approach over staging CT scan. Endoscopic ultrasonography fine needle aspiration (EUS-FNA), cystic fluid sampling, and endoscopic retrograde cholangiopancreatography (ERCP) are the most common options for pancreatic tissue biopsy. ERCP may be useful for evaluating the ductal anatomy, relationship to vascular structures, and relation to the lesion.

SELECTION CRITERIA

A minimally invasive approach for appropriate distal pancreatic neoplasms includes all benign lesions and neoplasms

without metastasis or local invasion, peritoneal seeding, or para-aortic lymph node metastasis. Cases with high malignant potential, such as invasive ductal cancer and mucinous cystic neoplasm, should be treated with *en bloc* resection of the spleen. Islet cell tumors and cystic diseases other than mucinous cystic neoplasms can be treated with spleen-sparing LDP. The ultimate success of any oncologic surgery depends on cancer-related survival. This specific oncological outcome is mainly driven by tumor biology, tumor margins, and adequacy of lymph node dissection.

Cystic pancreatic neoplasms

Most cystic neoplasms of the pancreas are benign but can range from completely benign simple cysts, serous cystadenomas, and pseudocysts to potentially premalignant mucinous cystadenomas and intraductal papillary mucinous neoplasms (IPMNs) to malignant IPMNs and malignant mucinous cystadenocarcinomas. Large neoplasm size, presence of symptoms, rapid tumor growth, and cyst fluid carcinoembryonic antigen level greater than 200 ng/mL should prompt surgery. A crucial point in LDPs for cystic neoplasm is tumor manipulation and potential rupture, which may be underreported.

Neuroendocrine tumors

These are rare neoplasms and can be functional or nonfunctional. They can manifest in association with an inherited syndrome, such as multiple endocrine neoplasia (MEN), or sporadically. Functional islet cell tumors of the pancreatic gland are insulinomas, gastrinomas, and glucagonomas. VIPomas and somatostatinomas are rarer forms of functional neuroendocrine tumors. It is noteworthy that insulinomas are generally solitary lesions evenly distributed

throughout the gland. Gastrinomas can be multifocal and difficult to localize, especially when associated with MEN syndrome.

Pancreatic ductal adenocarcinoma

Adequate lymphadenectomy provides useful staging to influence decisions regarding adjuvant therapy. The ratio of positive to procured lymph nodes has been shown to be of prognostic significance.

RESECTIONS

If splenectomy is anticipated, then vaccination against encapsulated bacteria (*Haemophilus influenzae*, *Streptococcus*, and *Meningococcus*) should be given 7–10 days in advance. Patients with functional pancreatic neuroendocrine tumors require physiologic status optimization before surgery. Preoperative antibiotics and deep venous thrombosis prophylaxis are provided according to Surgical Care Improvement Project (SCIP) guidelines. Patients are placed in the right lateral decubitus position using a beanbag. This position allows gravity to play a retractor role during mobilization (Figure 80.1). A nasogastric tube and a Foley catheter are usually placed after anesthesia induction. The operating surgeon and the second assistant stand on the right side of the patient, and the first assistant with the scrub nurse stand to the left of the patient. Pneumoperitoneum is established. Four trocars, two 5 mm trocars (one in the left flank and another in the epigastrium) and two 12 mm trocars (one in the periumbilical for the camera and another in the midclavicular line at the same level of the umbilicus) are placed. An additional 5 mm subxiphoid trocar is occasionally added to help in retracting the left lobe of the liver.



Figure 80.1 Patient positioning: oblique foot. (Courtesy of Intuitive.)

LAPAROSCOPIC DISTAL PANCREATECTOMY WITH *EN BLOC* SPLENECTOMY

Lesser sac exposure and splenic flexure mobilization

After exploring the abdomen for any metastases, the gastrotocolic ligament is divided using LigaSure (Valleylab, Boulder, Colorado) to open the lesser sac and to expose the plane between the posterior wall of the stomach and the body of the pancreas. Laparoscopic ultrasonography can be used to rule out vascular invasion, assess margins, and resectability to help in intraoperative decision-making. The short gastric vessels are divided up to the most cephalad short gastric vessel. The stomach is reflected cephalad and sutured to the abdominal wall, exposing the pancreas. The plane between the posterior stomach and the anterior surface of the pancreas is avascular and generally easy to develop. It is important during this step to place patients in reverse Trendelenburg position to allow gravity to drop the greater omentum. The splenic flexure is then mobilized by dividing the splenocolic ligament. This exposes the tail of the pancreas and the inferior pole of the spleen. The colon is reflected medially, and the white line of Toldt is divided to develop an adequate posterior plane for mobilization of the pancreas in the retroperitoneum. This plane is avascular, separating the mesocolon from Gerota fascia. Splenic attachments to the diaphragm should not be divided to prevent the spleen from flopping in the operative field.

Pancreatic mobilization

The inferior border of the pancreas is dissected out, and a window is created below the pancreatic edge, developing an avascular posterior plane between the pancreas and the retroperitoneum. Small branches of the splenic vein are divided until the posterior surface of the pancreas is fully visualized. The dissection is carried from lateral to medial past the target lesion. The inferior mesenteric vein is identified along the inferior edge of the pancreas.

Pancreatic transection and division of the splenic vein and artery

After confirming the site of division, the pancreas is retracted superiorly and anteriorly, and the dissection is continued caudal to cephalad exposing the splenic vein. The splenic vein is exposed posterior to the splenic artery, which is dissected along the superior border of the pancreas. Splenic artery and vein may be divided *en bloc* with pancreatic parenchyma. An endoscopic linear stapler with various thicknesses is used to divide the pancreas, depending on the tissue quality and thickness. In selected cases, the authors apply small titanium clips or fibrin glue along the staple line to control bleeding. Absorbable buttress material (Gore Seamguard) has been

used with the hypothesis to decrease the risk of bleeding and leaks. Furthermore, the pancreatic duct can be identified and sutured. The splenic artery and vein should be clearly identified and divided with a linear stapler. The authors usually use a 45 mm or 60 mm linear stapler, which is placed through the left-sided midclavicular port to allow a direct approach to the pancreas. An extended lymphadenectomy of the celiac trunk is performed if needed by dividing the attachment of the superior edge of the pancreas to the celiac trunk. Particular care is taken to identify and individually ligate the main pancreatic duct. Once the pancreas and splenic vessels are completely divided, the dissection is continued along the superior edge of the spleen medial to lateral by retracting the pancreas inferiorly to expose any attachment to the retroperitoneum. In a posterior radical antegrade modular pancreatectosplenectomy, the left adrenal gland and Gerota fascia are readily exposed. The spleen is freed of its posterior, lateral, and superior attachments. Some surgeons prefer a lateral to medial dissection; pancreatic dissection starts laterally by retracting the tail of the pancreas anteriorly and medially, dividing splenic vessels branches to the pancreas. Dissection is continued medially toward the point of transection. Hand-assisted LDP may bear some advantages in selected cases involving dense adhesions, obesity, and large tumors.

Specimen removal and drain placement

The specimen is placed in a sac and removed through the peri-umbilical port. If the LDP is done for neoplasm, the proximal pancreatic margin should be marked and sent for frozen section. Pathologic confirmation of a neuroendocrine tumor in the specimen is also a necessity, and the specimen should be sent for frozen section. A closed suction drain is placed in the left upper quadrant close to the pancreatic stump and brought out through the 5 mm trocar site. All fascial incisions greater than 10 mm should be closed.

Conversion to open distal pancreatectomy

Surgeons should be as comfortable performing ODP as performing LDP. An open approach is usually performed through a left subcostal incision or through an upper midline incision. Opening the lesser sac, division of the short gastric vessels, and mobilization of the splenic flexure and inferior border of the pancreas are then performed. After identifying the lesion, the pancreatic parenchyma is transected. The splenic artery and vein are isolated and ligated before or after, depending on surgeon preference.

Spleen-preserving distal pancreatectomy

There are two described techniques to preserve the spleen in LDP. After entering the lesser sac, the pancreas is dissected off the splenic vessels. The small branches of the splenic artery

and vein are divided using a sealing instrument starting near the presumed line of pancreatic division toward the splenic hilum. The tail of the pancreas is fully mobilized avoiding any injury to the splenic vessels, splenic parenchyma, or pancreatic parenchyma. In the Warshaw technique, the splenic artery and vein are ligated. Blood supply to the spleen is now preserved through the short gastric vessels. It is the authors' preference to preserve the splenic artery and vein to maintain the immunologic function of the spleen.

Pancreatic enucleation

Small tumors with indolent behavior located away from the main pancreatic duct are mostly suitable for laparoscopic or robotic enucleation using a laparoscopic ultrasound. As with LDPs, pancreatic fistula remains an issue.

ROBOTIC DISTAL PANCREATECTOMY

The da Vinci robot (Intuitive, Sunnyvale, California) is placed at the patient's left shoulder (Figures 80.2 and 80.3).

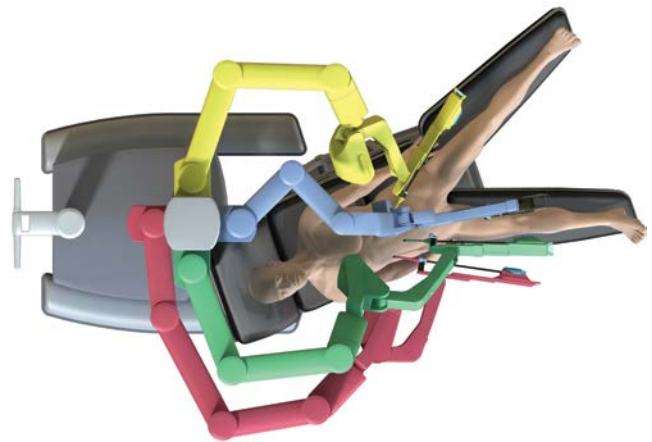


Figure 80.2 Top view of the operating room table and robot. (Courtesy of Intuitive.)

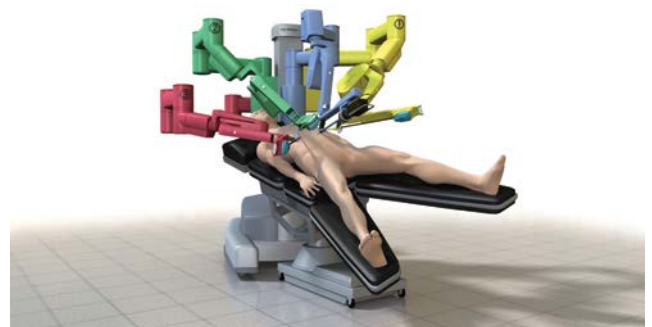


Figure 80.3 Docking and position of operating room table. (Courtesy of Intuitive.)

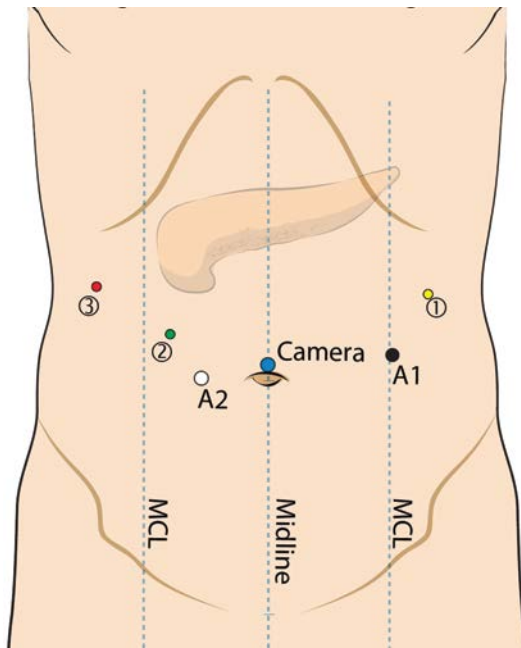


Figure 80.4 Port placement: robotic distal pancreatectomy. (Courtesy of Intuitive.)

Four trocars are used: 12 mm optical port at the umbilicus, two robotic 8 mm ports in the left midclavicular, and one robotic 8 mm port in the right midclavicular. An additional 12 mm port is placed in a lower position between the camera and the port of the left midclavicular, which is used by the assistant to staple the pancreas (**Figures 80.4 and 80.5**). As previously described, dissection is started with a coloepiploic division using the monopolar scissors, which is started in the middle and then carried on to the left in order to lower the splenic flexure while entering the lesser sac. The stomach is retracted cephalad, and the anterior gastric surface is sutured to the abdominal wall. Dissection is then continued at the inferior border of the pancreas where the middle colic vein is identified and followed up in order to identify the superior mesenteric vein. Small collateral branches are clipped and divided by means of small metallic clips. A retropancreatic plane is created along the venous mesenteric-portal axis and then carried on at the superior border of the pancreas in order to identify and skeletonize the splenic artery. Care must be taken to stay on the left side of the aorta during this dissection to avoid a potential detrimental injury to adjacent venous structures. A very useful landmark is the left gastric artery that can be identified at its origin off the celiac trunk running toward the lesser gastric curvature. Once

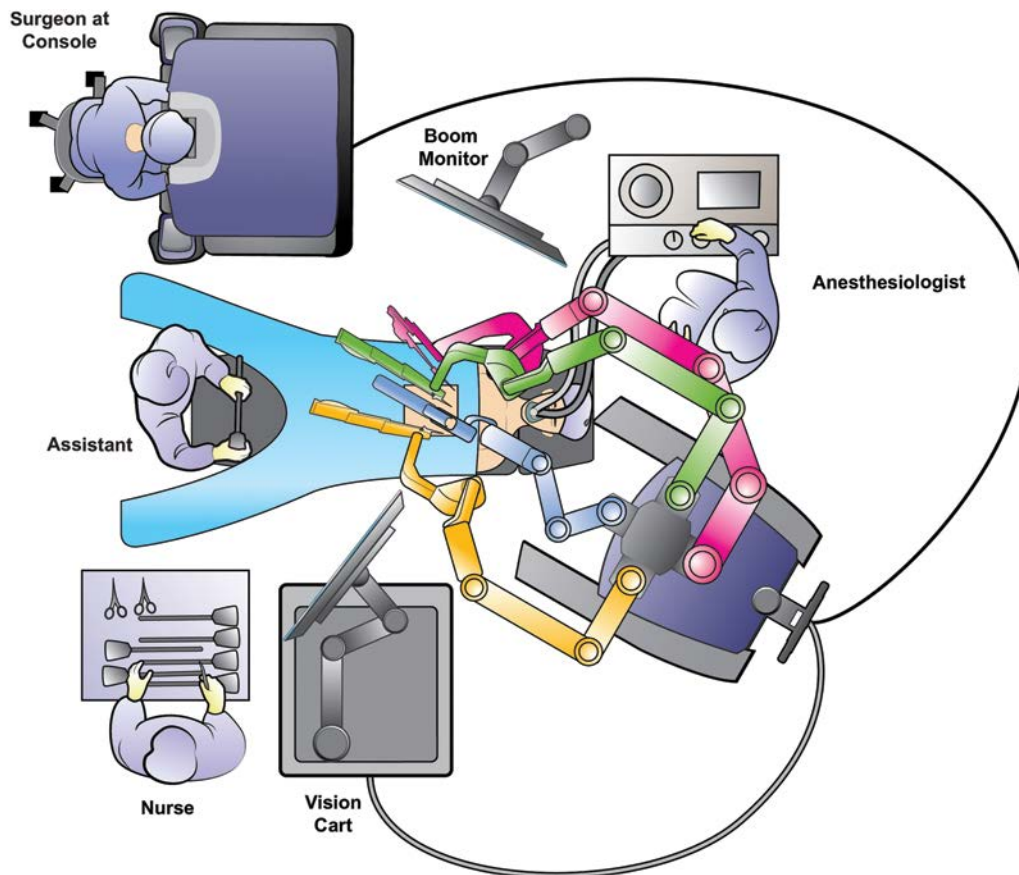


Figure 80.5 Operating room setup: robotic distal pancreatectomy. (Courtesy of Intuitive.)

identified, a vessel loop is placed around the splenic artery. The pancreatic neck is placed in surgical tape and gently lifted upward by the assistant's grasper exposing the splenic vein and controlled by a vessel loop. An articulated stapler to the left border of the mesenteric-portal axis transects the pancreas. Dissection is then carried on clockwise, freeing the pancreas from the splenic vessels. Gradually the dissection is continued all the way to the splenic hilum, allowing for a complete resection of the pancreatic tail, while preserving splenic vessels and the spleen.

POSTOPERATIVE CARE AND PANCREATIC FISTULAS

According to the 2005 International Study Group of Pancreatic Fistula (ISGPF), a pancreatic fistula is defined as output via an operatively placed drain (or a subsequently placed percutaneous drain) of any measurable volume of drain fluid on or after postoperative day 3, with an amylase content greater than three times the upper normal serum value; each pancreatic fistula was classified as grade A, B, or C. The clinical manifestations as defined by ISGPF range from asymptomatic fluid drainage in closed suction drains to life-threatening sepsis requiring surgical intervention. Several trials have investigated methods of resolving the ongoing debate about prevention of pancreatic fistula in LDP. Identification and selective ligation of the main pancreatic duct remain a challenging step in the laparoscopic approach and is considered one of the steps at the authors'

institution. The multi-institutional DISal PAnCreaTectomy (DISPACT) trial, a randomized controlled trial done in 21 European hospitals was designed to assess the effect of stapler versus hand-sewn closure on formation of postoperative pancreatic fistula after DP. This study did not show any difference in postoperative pancreatic fistula.

SUMMARY

There has been a tremendous growth in the number of reports concerning LDP and RDP. Greater emphasis is applied to patient outcomes (pancreatic fistula, morbidities, and hospital stay). As experience and technology evolve, multi-institutional studies with long follow-up are necessary to validate the long-term oncologic survival outcomes for patients with pancreatic malignancy beyond safety and feasibility of doing such procedures.

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Laparoscopic surgery of the spleen

NAMIR KATKHOUDA, VIVIAN PHAM, AND KULMEET SANDHU

INTRODUCTION

The first successful laparoscopic splenectomy was performed by Delaitre and Maignien in France in 1991. Since its introduction, the benefits of laparoscopic splenectomy have been undeniable. Compared with the open technique, laparoscopic splenectomy has a lower morbidity and mortality rate, less blood loss, and a shorter hospital stay. Laparoscopic splenectomy is the ideal technique for the normal-sized spleen, but an open splenectomy may be the better option for patients with portal hypertension or massive splenomegaly.

SURGICAL ANATOMY

Knowledge of the anatomy of the spleen is critical, as it will help determine the most appropriate dissection technique. Spleens with a magistral vascular distribution are relatively smooth and usually have a single pedicle forming the splenic hilum. Notched spleens and those with prominences have a distributive vascular pattern where multiple terminal branches are noted to enter the spleen (**Figure 81.1**). The tail of the pancreas lies close to the hilum, and in 40% of cases, it is found within 1 cm of the spleen. In about 30% of cases, the tail of the pancreas is in direct contact with the spleen. Therefore, caution is recommended before firing a linear cutter stapler across the hilar vessels.

PREOPERATIVE MANAGEMENT

It is essential that patients presenting with hematologic disorders are worked up appropriately by the referring hematologists. The patient should be vaccinated against

pneumococcus, *H. influenza*, and meningococcus at least 2 weeks prior to surgery. The anesthesiologist must ensure that there is a suitable blood and platelet supply in the operating room prior to the start of the procedure. An orogastric tube is placed to decompress the stomach.

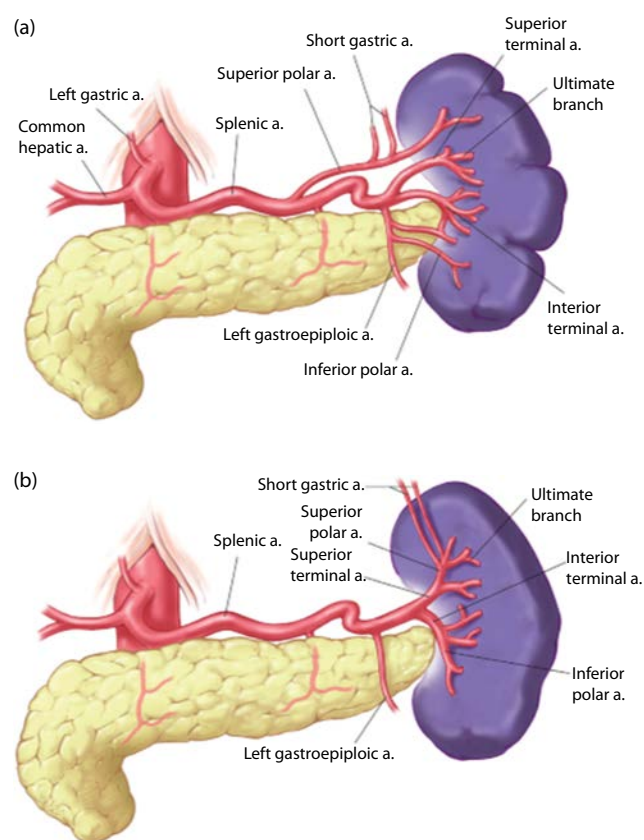


Figure 81.1 Vascularization of the spleen: (a) *Distributed* type (multiple splenic notches). (b) *Magistral* type (few splenic notches).

Clip applicators, atraumatic graspers, liver retractors, and an irrigation suction machine with the capacity for hydrodissection should be available for the case. Harmonic shears (Ethicon Endosurgery Inc.) are also useful because they can reduce the number of clips used during division of the short gastric vessels and can also function as a grasper. An open tray should be immediately available in case there is a need for conversion.

POSITIONING

The patient is secured on a beanbag with the left side up at a 60° angle in reverse Trendelenburg. The left arm is positioned as for a left lateral thoracotomy. This position allows gravity to pull the stomach and small bowel in a rostral direction out of the operative field. Also, the spleen is kept hanging from the diaphragm by its phrenic attachments, placing the gastrosplenic vessels under tension, simplifying dissection and division of these vessels. This is the “hanging spleen” technique described by Delaitre and Gagner.

The surgeon stands on the patient’s right side facing the left monitor, with the camera assistant on the same side. The first assistant stands on the opposite side (Figure 81.2). In the anterior approach, the hilar vessels are controlled first, and the phrenic attachments are divided at the end of the

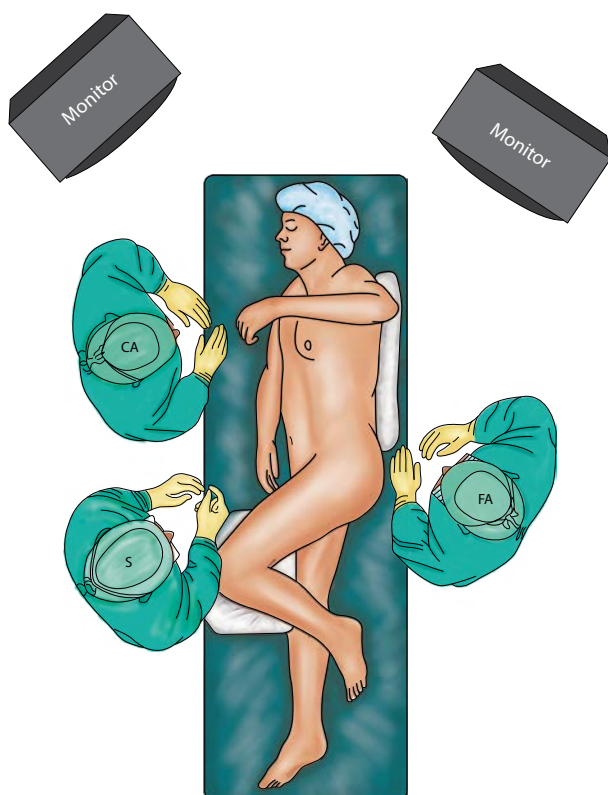


Figure 81.2 Operating room setup. (CA, camera assistant sitting on a chair; FA, first assistant; S, surgeon.)

operation. In contrast, with a posterior approach, the lateral attachments are divided first, the spleen is mobilized medially, and the hilar vessels are controlled later, as done in open surgery (Figure 81.3).

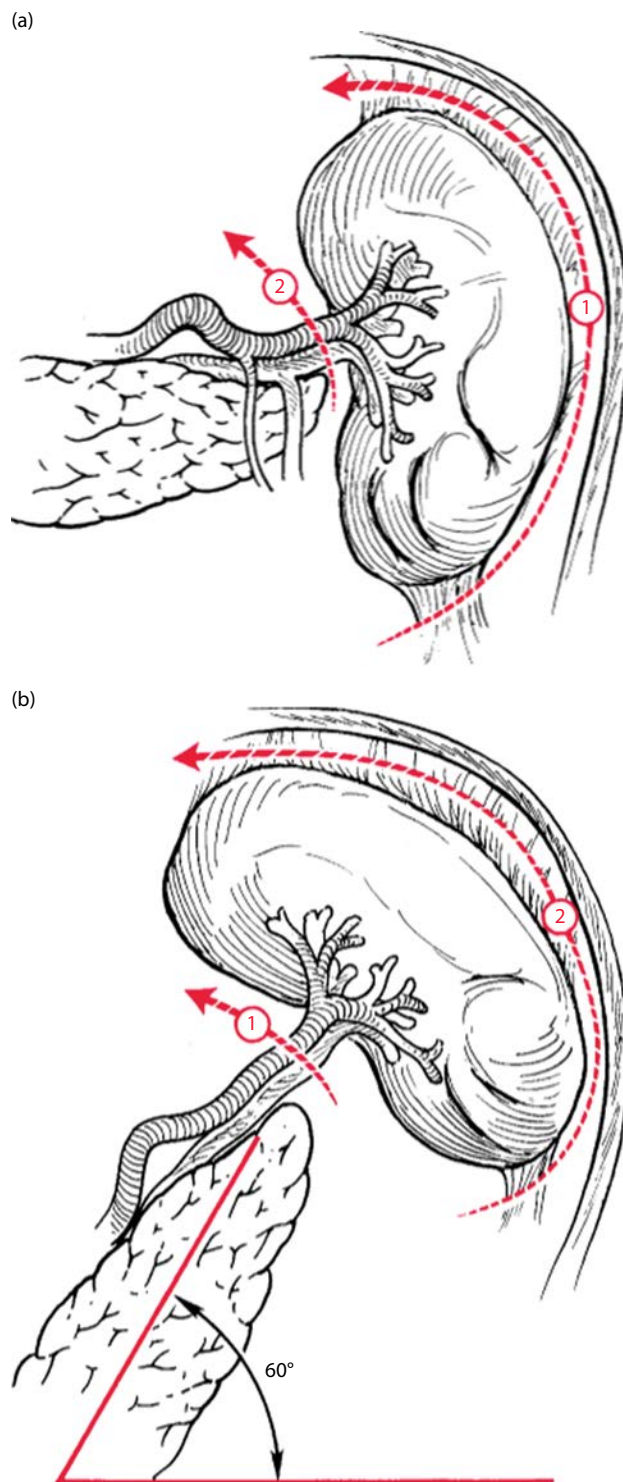


Figure 81.3 (a) Open splenectomy/posterior laparoscopic technique. (b) Anterior laparoscopic technique. Numbers depict stages of the operation.

TROCAR PLACEMENT

Four to five ports are needed for this operation (**Figure 81.4**). Following insufflation using a Veress needle, the first trocar for the 30° telescope is inserted in the left upper quadrant approximately five fingerbreadths below the costal margin. A Hasson trocar can be utilized in cases of splenomegaly or after two failed attempts with the Veress needle. One port is inserted on each side of the umbilical port in a triangulated manner, for the right and left hands of the surgeon. Another trocar is inserted laterally under the left costal margin for the first assistant. An optional subxiphoid trocar can be inserted for an irrigation/suction device or for a fan retractor.

ANTERIOR VERSUS POSTERIOR APPROACH

The anterior technique uses gravity to expose the splenic hilum and stabilize the spleen. The posterior approach has improved exposure of the hilar vessels. We favor the anterior approach because, in the case of hilar bleeding, the spleen remains attached to the diaphragm and does not get in the way of controlling the bleeding.

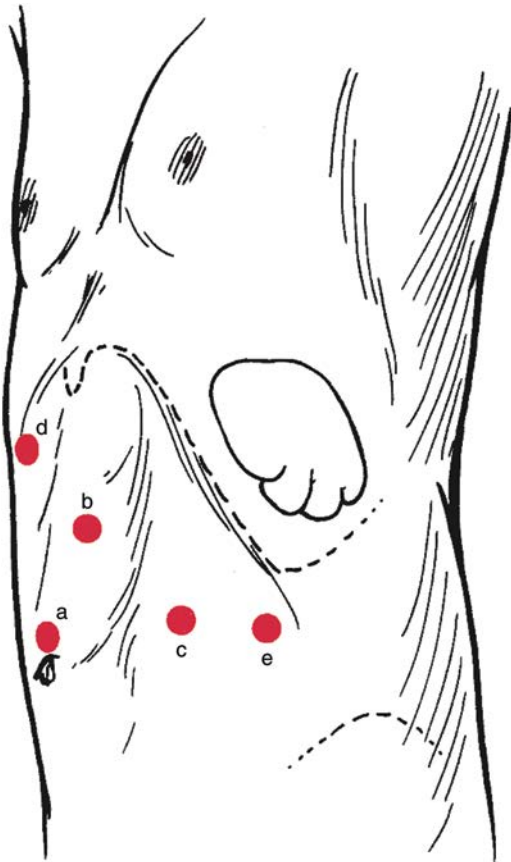


Figure 81.4 Port positions for laparoscopic splenectomy: (a) umbilical telescope; (b) surgeon's left hand; (c) surgeon's right hand; (d) subxiphoid port for irrigation/suction or an assistant's grasper; and (e) first assistant's grasper.

ANTERIOR TECHNIQUE

Exploration

Prior to dissection, full exploration of the abdominal cavity is recommended to check for the presence of accessory spleens and other intra-abdominal lesions. A systematic approach facilitates completeness of the inspection as the presence of accessory spleens has been reported to be as high as 24%.

Division of the short gastric vessels and exposure of the tail of the pancreas

The first step is division of the short gastric vessels and entry into the lesser sac along the greater curvature of the stomach. The first assistant grasps the fatty tissue surrounding the short gastric vessels and retracts it superiorly, while the surgeon gently retracts the stomach fundus to the right. This exposes the short gastric vessels, which are subsequently ligated and divided with the harmonic shears. Clips can be added for larger vessels as needed. The division is continued superiorly and then inferiorly until the tail of the pancreas is completely exposed.

Exposure of the inferior pole of the spleen and division of the inferior pole vessels

The first assistant retracts the spleen superiorly and laterally with a closed Babcock clamp to expose the splenic flexure of the colon. The surgeon's left hand retracts the transverse colon inferiorly, exposing the splenocolic ligament. The ligament is divided using the harmonic shears while leaving a bundle of connective tissue on the spleen. This tissue allows for eventual indirect grasping of the spleen, minimizing direct manipulation of the spleen and the risk of capsular tear. Once the splenocolic ligament has been divided, lateral and superior retraction will expose the inferior pole vessels that branch from the main splenic vessels. The inferior pole vessels are divided at this point, permitting full mobilization of the inferior pole of the spleen. These vessels are usually large in size and should be clipped or divided using an endo-GIA stapler with a vascular cartridge. The use of the harmonic shears is not recommended on these vessels, as it will not achieve sufficient hemostasis.

Division of the hilar vessels and phrenic attachments

In order to expose the hilar vessels, opposing retraction by the first assistant and the surgeon is required. The first assistant retracts the mobilized inferior pole of the spleen superiorly and laterally. The surgeon gently pushes the exposed tail of the pancreas down, creating access to the

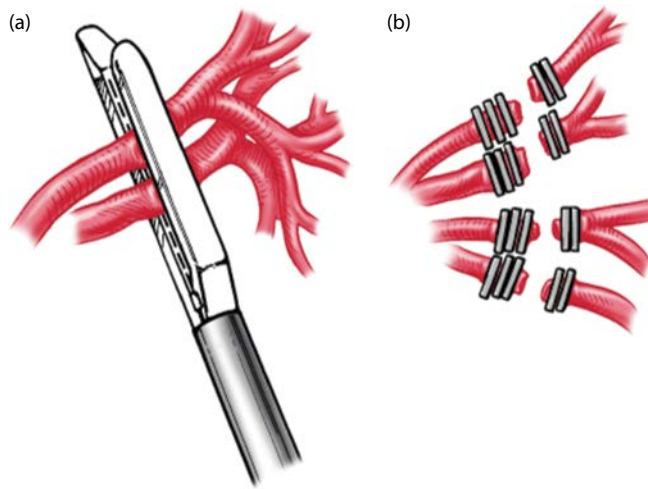


Figure 81.5 Division of the splenic vessels. (a) Stapler firing with simultaneous control of both vessels. (b) Separate control of the artery and vein using large clips.

hilum and the main splenic vessels. Division of the hilar artery and vein is a critical step that should be performed meticulously to avoid any bleeding. Use of a blunt right-angled dissector is a safe option for dissection in this area. The surgeon has two choices for ligation of the splenic vessels at the hilum of the spleen: transection of the vessels with a firing of an Endo-linear cutting stapler using a vascular cartridge (**Figure 81.5a**), or a more formal division of the artery and vein separately between clips (**Figure 81.5b**). In spleens where the artery and vein enter the hilum as a single pedicle, the stapler can be used to transect the vessels as a compact bundle. For hilar vasculature that has multiple branches, the use of clips is recommended to individually divide the terminal branches. Finally, the attachments of the spleen to the diaphragm are divided, allowing full mobilization of the spleen.

Extraction of the spleen in a bag

The next step is introduction of the retrieval bag. Using hilar and fatty attachments as a handle, the spleen is rolled onto its convex surface and shoved in a gentle sliding motion into the bag. The fascia of the umbilical port can be slightly enlarged to allow for extraction of the bag. The introduction of two fingers (or a ring forceps) to squeeze the spleen between the fingers and the anterior abdominal wall will enable morcellation of the spleen and extraction of both the bag and the splenic fragments. Care should be taken not to drop any fragments in the abdomen, which can lead to splenosis and recurrent disease.

The spleen bed is then checked for hemostasis. Drains are used in very select cases and depend on the surgeon's experience. In particular, it depends on the degree of trauma to the tail of the pancreas during the dissection.

POSTERIOR TECHNIQUE

1. Exploration
2. Division of the splenocolic ligament
3. Division of the inferior pole vessels.
4. Division of the phrenic attachments
5. Exposure and division of the hilar vessels
6. Division of the short gastric vessels
7. Extraction of the spleen in a bag

The surgeon begins the procedure by taking down the inferior pole vessels, as described for the anterior approach. After division of these vessels, the spleen is gently retracted medially and the splenophrenic ligament is divided using the harmonic shears. This dissection continues superiorly until the short gastric vessels are encountered. Careful dissection of the splenorenal ligament is then performed, with caution taken to avoid injury to the left adrenal gland. Next, the short gastric vessels are divided using the harmonic shears and clips as needed. The hilar vessels will now be in view and can be dissected with a right angle dissector before being divided separately or together with a vascular load of the endolinear cutting stapler (**Figure 81.6**). Then, the short gastric vessels are divided using the harmonic shears. The remainder of the operation is performed as described for the anterior approach.

POSTOPERATIVE CARE

The postoperative course following laparoscopic splenectomy is straightforward. Serum amylase and lipase levels should be checked on the first postoperative day to ensure

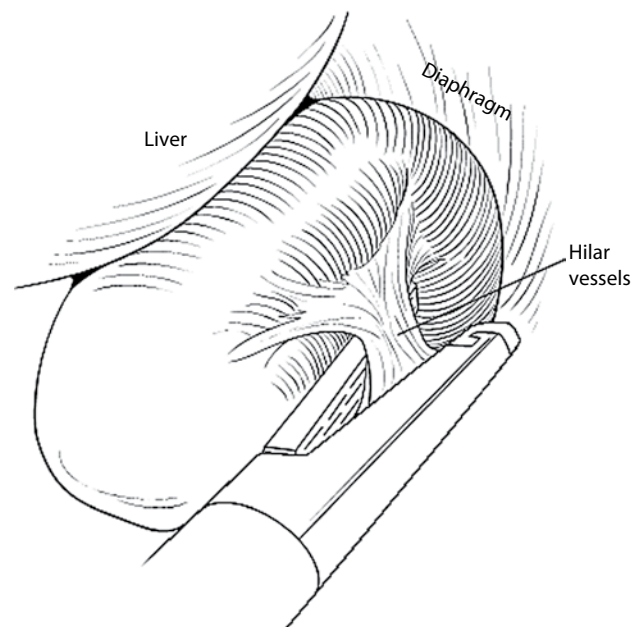


Figure 81.6 Posterior approach. Division of the pedicle with a stapler using the vascular load cartridge.

there has been no pancreatic injury. A clear liquid diet is initiated if the levels are normal, and the patient can be discharged home once the diet has been tolerated. If a drain was placed, and provided the amylase levels in the drain are within normal range, it is removed prior to discharge.

MANAGEMENT OF COMPLICATIONS

Bleeding constitutes a major problem intraoperatively. Three etiologies are possible: bleeding from an unnamed vessel, bleeding from a major vessel, or bleeding from a splenic injury.

Control of an unnamed vessel

The first step is to pull back on the scope to protect the lens from blood. The vessel is then clamped using an atraumatic grasper. Irrigation and aspiration of the surgical site should follow to evaluate the rate of bleeding. If the bleeding has been controlled, clips are placed appropriately. Sometimes, electrocautery will control the situation and allow safe placement of the clips. Compression using a 2×2 cm gauze can sometimes be used to control the bleeding, allowing the operative site to be cleaned in preparation for hemostasis.

Control of a major vessel

The situation is different when a major vessel is injured, such as the splenic vein or artery, or the direct terminal branches of the main trunk. Flow is usually very high in these vessels, and blood will often obscure the view. In these circumstances, attempt to control the bleeding using the steps described previously, using a larger atraumatic instrument such as a bowel clamp to grasp the whole hilum. If unsuccessful, it is usually wise to convert the patient rapidly through an open left subcostal incision.

Splenic injury

Another possibility is injury to the spleen during the dissection. In general, this is not a reason for conversion to an open procedure. A forceful retraction, for example, can tear the capsule. Although resultant bleeding may obscure the dissection, compression with a 2×2 cm surgical gauze together with electrocautery should control bleeding.

Maneuver of last resort during bleeding of the hilar vessels

In the event of a splenic injury in traditional open surgery, the surgeon rapidly mobilizes the splenic attachments after inserting a large piece of gauze to compress the hilum. The

surgeon's left hand retracts the splenic handle, and the right hand clamps the vessels *en bloc* using large and long Kelly clamps. The same maneuvers can be realized laparoscopically if the surgeon and assistant have advanced laparoscopic skills.

The hilum is compressed using a large 4×4 cm gauze, and the bleeding is controlled. As the short gastric vessels and the inferior attachments are already divided, the surgeon should promptly divide the phrenic attachments to mobilize the spleen. Once the spleen is mobilized, the assistant can retract the whole spleen superiorly with an open fan retractor, and the surgeon fires one or two shots of a linear cutting stapler with vascular loads. This should be done quickly and staying as close as possible to the spleen to avoid pancreatic injury. If this maneuver is not successful, conversion to an open procedure should be initiated.

PARTIAL SPLENECTOMY

It is also possible to perform a partial laparoscopic splenectomy. In order to accomplish this, it is important to identify the inferior pole vessels, or any vessel per se, that is supplying the territory that has to be removed. Once the vessel is isolated using a right angle dissector, clips are placed and the vessel is divided, immediately producing a zone of ischemia in the spleen (Figure 81.7). Once this has been achieved, harmonic shears are used to perform a partial splenectomy. Our preference is to use harmonic shears as they allow for permanent hemostasis. It is important to leave 2 or 3 mm of zonal ischemic tissue on the remaining healthy spleen, and divide the spleen in the ischemic territory to avoid massive

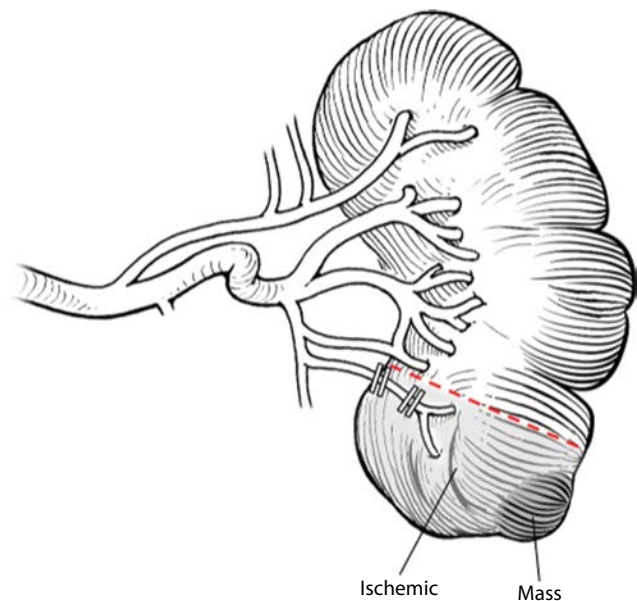


Figure 81.7 Partial splenectomy. Ligation of the inferior pole vessels, in this example, that delineates a segmental zone of ischemia.

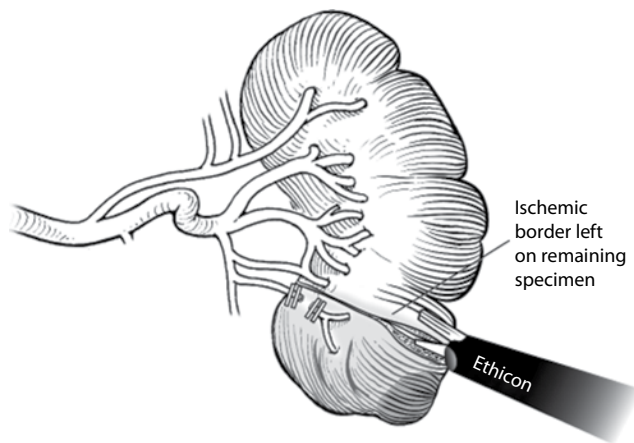


Figure 81.8 Partial splenectomy. Division of the splenic parenchyma using the harmonic shears, just beneath the line of ischemic demarcation.

bleeding (**Figure 81.8**). Once the partial splenectomy is performed, fibrin sealant is sprayed on the remaining tissue to further promote homeostasis. The specimen is removed as described previously.

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Minimally invasive approach to endocrine disease



William Hogarth, *Four Stages of Cruelty—The Reward of Cruelty*, 1751. Line engraving, 15 1/4 × 12 3/4 inches.
(Artwork in the public domain; image courtesy Yale Center for British Art.)

In his *Autobiographical Notes*, William Hogarth explains that the images in his *Four Stages of Cruelty* “were done in the hopes of preventing in some degree that cruel treatment of poor Animals which makes the streets of London more disagreeable to the human mind, than anything whatever, the very describing of which gives pain.” The moralizing series seeks to deromanticize criminality, such as animal cruelty, which Hogarth saw as rampant in London at the time. It follows the brief life of protagonist Tom Nero as he goes from being a ward of the parish of St Giles-in-the-Fields to a criminal, sentenced to death by hanging at Tyburn gallows near London. During this time, the aptly named Nero commits a series of increasingly atrocious acts, first abusing dogs as a teenager, to beating a horse in the street as a young man, to committing highway robbery and killing his pregnant lover as an adult. The final episode of the series, seen here, shows Nero’s lifeless body being dissected by a group of surgeons for an anatomical demonstration in the Cutlerian theater near Newgate prison, a common occurrence following the execution of criminals in England in the

eighteenth century. The specimen is recognizable as Nero by the noose around his neck, which echoes the splayed intestine about to be devoured by a hungry hound from below. Much like a high court judge, the chief surgeon presides over the scene from a high-backed chair, above which hangs the royal coat of arms. His long cane points toward Nero’s abdomen, into which a surgeon handling a blade reaches with an ungloved hand. The corpse is further explored by other investigators who open his eye socket and feet with large scalpels for the benefit of the crowd in the theater. The implication is that judgement and punishment extend beyond Nero’s sentencing and violent demise, which is further underscored by the presence of a makeshift incinerator for former “specimens” at left and the malicious skeletons pointing toward each other that frame the scene.

Quote from William Hogarth, “Autobiographical Notes,” in The Analysis of Beauty, ed. Joseph Burke (Oxford: Clarendon Press, 1955), 226.

Laparoscopic adrenalectomy

JESSE D. PASTERNAK AND QUAN-YANG DUH

INTRODUCTION

Adrenalectomy is indicated for hypersecretion of hormones or concern for cancer. Open adrenalectomy requires a large subcostal or a lumbar incision and is relatively morbid. Laparoscopic adrenalectomy, first described in 1992, has the same advantages as other laparoscopic operations.¹⁻³ While there are no randomized controlled trials comparing open and laparoscopic adrenalectomy, there are multiple studies showing the expected benefits of laparoscopy, including less postoperative pain and blood loss, shorter hospital stay, and earlier return to work.⁴⁻⁶

In this chapter, we outline the indications for laparoscopic transabdominal (lateral) adrenalectomy and focus on the technical aspects of the operation, including patient setup, adrenal dissection, and tissue extraction. In this chapter, we do not describe the retroperitoneal approach or the robotic adrenalectomy.

INDICATIONS AND CONTRAINDICATIONS

The most common indications for adrenalectomy are hormone hypersecretion or concern for cancer. Patients may be referred for surgery because of adrenal “incidentalomas” found on computed tomography or magnetic resonance imaging done for other reasons. Some will have already been evaluated by endocrinologists and found to be secreting hormones; however, these lesions most commonly are nonsecreting adenomas. Other patients may have adrenal metastasis from a nonadrenal primary or have primary adrenocortical cancer.

All patients with an adrenal tumor need to be worked up for hormonal hypersecretion. Functional adrenal tumors include cortical adenomas (or rarely carcinomas), which may cause hypercortisolism (Cushing syndrome), and pheochromocytomas, which secrete metanephrines. Pheochromocytomas are diagnosed by elevated plasma

free metanephrines or urinary fractionated metanephrines. Cushing syndrome is diagnosed by one of (1) an elevated 24 hour urine free cortisol, (2) an abnormal midnight salivary cortisol, or by (3) a non-suppressed low-dose dexamethasone suppression test with suppressed ACTH. Primary aldosteronism is diagnosed by an elevated plasma aldosterone to plasma renin activity ratio. Adrenocortical cancer can have a mixture of hormonal hypersecretion including DHEA-sulfate. Risk of adrenocortical cancer is assessed by imaging characteristics and by size. Adrenal tumors that are large (>4 cm) or irregular appearing, or have high density on noncontrast scans and slow washout on contrast scans are at higher risk for cancer and should be considered for resection⁷ (**Table 82.1**).

For adrenal lesions not meeting criteria for resection, imaging and biochemical testing can be repeated after 3–6 months and subsequently every year for 5 years. There is little evidence to recommend longer-term imaging follow-up; however, up to 20% of patients will develop subclinical Cushing syndrome in this surveillance period.^{8,9}

Adrenalectomy can be performed for isolated adrenal metastases most commonly from non-small cell lung cancer, renal cell carcinoma, and melanoma.¹⁰⁻¹² Percutaneous biopsy of the adrenal gland is rarely indicated and should be performed only after pheochromocytoma and adrenal cortical cancer have been ruled out.¹³ Many adrenal metastases can be removed safely laparoscopically.¹⁴ Larger adrenal metastases are often associated with dense fibrotic periadrenal adhesions, and the surgeon should have a low threshold to convert to an open operation.

Contraindications

Contraindications for laparoscopic adrenalectomy are oncological and technical. Malignant pheochromocytomas, known adrenocortical carcinomas, and very large tumors

Table 82.1 Indications for laparoscopic adrenalectomy

Functioning lesions	Nonfunctioning lesions
<i>Benign</i>	<i>Benign</i>
• Aldosteronoma • ACTH-independent Cushing syndrome (adenoma, hyperplasia) • ACTH-dependent Cushing syndrome, when ACTH source cannot be controlled • Pheochromocytoma	• Cortical adenoma • Myelolipoma^a • Simple cyst^a
<i>Malignant</i>	<i>Malignant</i>
• Adrenocortical cancer^b • Malignant pheochromocytoma^b	• Metastasis • Adrenocortical cancer^b

Source: Lal G, Duh Q-Y. *Surg Oncol* 2003;12(2):105–23.⁸

^a Adrenalectomy only indicated if lesions are large and symptomatic.

^b Most require open resection. The role of laparoscopic adrenalectomy is controversial.



are more difficult to resect laparoscopically. Tumors with invasion into surrounding periadrenal structures or bulky lymphadenopathy should be resected by an open approach.¹⁵ Breaching the capsule of a malignant tumor increases the risk of local recurrence. Fracturing even a benign pheochromocytoma can lead to pheochromocytomatosis and recurrent disease. In general, tumors larger than 10–12 cm on the left and 8–10 cm on the right need an open approach.^{6,8}

Risks of operation

Risks of laparoscopic adrenalectomy can involve those related to anesthesia as well as the patient's medical fitness. While uncommon, cardiac, respiratory, and thromboembolic events can complicate these operations, especially in physiologically active tumors such as pheochromocytoma. An experienced anesthesiologist and good preoperative medical management are paramount. An experienced endocrinologist is very helpful in considering alpha blockade and hydration in patients with pheochromocytoma.

Other risks for laparoscopic adrenalectomy include bleeding, infection, and injury to adjacent structures, including the liver, IVC and kidney on the right, and spleen, pancreas, colon, and kidney on the left. Infection risk is low except in patients with hypercortisolism, in whom perioperative antibiotics is recommended.¹⁶

TECHNICAL CONSIDERATIONS

Equipment

There is wide variation in equipment used for laparoscopic adrenalectomy. We use a 10 mm, 30° laproscope and 4 laparoscopic ports. Extra ports can be placed if needed for exposure. We prefer L-hook cautery for precise dissection of tissue planes. In addition, many surgeons also use advanced energy devices, namely a bipolar vessel sealing instrument or

ultrasonic shears. A metal clip applicator is often used to control the adrenal vein although advanced energy devices may be appropriate. A fan retractor is used for retraction of the liver on the right and spleen on the left and rolled-sponges and suction irrigator are used to ensure a clear operative field.

Patient positioning

Under general anesthesia, after establishing arterial and venous access and inserting a urinary catheter, the patient is positioned in the lateral decubitus position. For bilateral adrenalectomy, the patient is repositioned after the first adrenal gland is removed. We place the patient on a beanbag. An axillary roll is used. The table is flexed at the lower ribcage to widen the distance between the hip and the costal margin, allowing ample room for laparoscopic port placement.

Right adrenalectomy

For a right adrenalectomy ([Video 82.1](#)), four ports are placed subcostally evenly spaced from the midclavicular to anterior axillary line. We usually place the initial port using a Veress needle, but an open technique is used if there is any difficulty establishing pneumoperitoneum. We use dilating-type ports and usually do not suture close the port sites. The assistant and the surgeon both stand facing the front of the patient, with the assistant cephalad.

The assistant uses the most medial port to retract the liver superiorly and medially to expose the space between the liver and kidney. The peritoneal reflection is incised next to the liver, taking down the triangular ligament. Dissection in this space “opens the book,” with the liver retracted anteriorly and the adrenal gland and the kidney remaining posteriorly. The superior border of the adrenal gland is exposed and dissected from the diaphragm. The superior adrenal artery is found at the mediosuperior border and is usually ligated with the vessel-sealing device. This opens the superior part of the adrenal gland to be retracted laterally creating a “V” and enlarges the space between the adrenal gland laterally and the liver and IVC medially. Dissecting in this space at the tip of the “V” working from known to unknown areas, the medial edge of the adrenal gland is dissected away from the IVC. The right adrenal vein is identified as a short vessel draining from the medioanterior adrenal into the IVC. The adrenal vein is lengthened by dissecting cephalad and caudad to where it joins into the IVC. There are many adrenal vein anatomical variants,¹⁷ but most commonly there is a single short vein draining into the lateroposterior part of the IVC. The right adrenal vein is then isolated and clipped, leaving two clips on the IVC side. In highly vascular tumors such as pheochromocytomas, clipping of the vein too early before devascularizing the gland will cause venous congestion and bleeding from the tumor. Once the right adrenal vein is taken, the gland can be retracted away from the IVC, making subsequent dissection easier and safer.

After the adrenal vein is transected, the space between the gland and the IVC is widened. Dissection is continued inferiorly, following the medioinferior border of the adrenal gland. This edge of the adrenal is usually thin and described as the “pancake portion,” and it sometimes extends quite inferiorly toward the renal hilum. A superior pole branch artery to the upper pole of the kidney is nearby and must be avoided during the dissection. If this branch is inadvertently ligated, an ischemic upper pole of the kidney will cause postoperative hypertension. Once this lower part of the adrenal is freed from the renal hilum, the sealing energy device is used to free the adrenal gland from the upper pole of the kidney.

Left adrenalectomy

Similar to the right side, four ports are placed about 1 cm below the costal margin between the midclavicular and anterior axillary line. The assistant, standing cephalad to the surgeon, uses the most medial port for retraction and adjacent port for the camera. The two lateral ports are used by the surgeon.

The splenic flexure is dissected free from the spleen and lateral abdominal wall. The lateral attachments of the spleen are dissected and together with the tail of the pancreas are retracted medially to expose the adrenal gland and kidney posteriorly. The dissection is continued in this avascular plane, “opening the book,” freeing the spleen and tail of the pancreas anteriorly from the kidney and the adrenal gland posteriorly. The dissection should continue until the gastric fundus becomes visible, described as the “sunrise of the stomach.” The adrenal gland dissection is continued at its medio-superior border. The superior adrenal artery is identified and transected. At the medial border of the adrenal gland, the inferior phrenic vein is identified and can be followed inferiorly until it joins the left adrenal vein. Another way to find the left adrenal vein is by following the imaginary line extending laterally from the splenic vein. The left adrenal vein is joined by the inferior phrenic vein, which then drains into the renal vein. Because the left adrenal vein is usually long, the left renal vein does not usually need to be dissected. The adrenal vein is clipped and divided, leaving two clips on the renal vein side. Dissection is then continued around the inferior border of the medial limb (“pancake part”) of the adrenal gland, away from the renal hilum and avoiding the superior pole renal artery branches. Once freed from the renal hilum, the adrenal gland is dissected off the mediosuperior kidney and freed from all remaining lateral attachments.

EXTRACTION OF SPECIMEN

The dissected specimen usually includes the tumor, the remaining adrenal gland, and the surrounding periadrenal tissue. Once the specimen is detached, the operative field is checked for hemostasis and irrigated if necessary. Fracturing even benign tumors can risk seeding of tumor cells.¹⁸ We therefore use a strong and impermeable nylon bag to capture and extract the specimen. Thinner bags are easily broken and risk tumor spillage. The specimen can be

morcellated in the bag and extracted or removed whole by enlarging a port site. Drains are not usually used.

POSTOPERATIVE CARE

After surgery, most patients can eat a regular diet and be monitored on the surgical ward. Patients with pheochromocytoma spend 4 hours in the postanesthesia care unit, and if they remain hemodynamically stable without need for vasopressor support, they, too, can be sent to the surgical ward. Otherwise, they may need intensive care unit admission for blood pressure management. These patients must also have regular blood glucose monitoring for potential hypoglycemia postoperatively. Patients with Cushing syndrome must receive exogenous steroids perioperatively, often in close consultation with an endocrinologist. In general, most patients can be discharged from the hospital the day after the operation.

POTENTIAL FUTURE DIRECTIONS

In addition to the transabdominal or “lateral” approach, minimally invasive adrenalectomy is performed through a posterior retroperitoneal approach with excellent results. This was first described by Mercan in 1995 and popularized by Walz thereafter.^{19,20} Similar principles of preoperative workup apply regardless of the operative approach. A recent, single-center randomized trial favored the retroperitoneal approach.²¹ In general, the transabdominal approach can accommodate dissection of larger adrenal tumors and provides an easier route to conversion compared to the retroperitoneal method. Robot assisted adrenalectomy by both the anterior transabdominal approach as well as the posterior retroperitoneal approach have been found to be safe but expensive and associated with a long learning curve.

VIDEO

Video 82.1 Transabdominal laparoscopic right adrenalectomy (<https://youtu.be/fCOCcuHbqml>).

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Endoscopic approaches to the thyroid and parathyroid glands

HYUNSUK SUH AND WILLIAM B. INABNET III

INTRODUCTION

Since the establishment of modern thyroid and parathyroid surgeries by some of the most prominent surgeons such as Theodor Billroth, Emile Theodor Kocher, and William Halsted, various forms of endoscopic and robotic approaches have evolved over the past few decades.

Following the trend in minimally invasive surgeries (MISs), endocrine surgery also evolved toward more focused incisions and dissections, while certain approaches have deployed endoscopic techniques. Endoscopic thyroid and parathyroid surgeries initially started with a cervical approach, but soon evolved to more distal sites such as axilla, breast, postauricular crease, or mouth to fully utilize the endoscopic principles while avoiding a conspicuous neck scar. These approaches are referred to as remote-access surgeries, and contrary to the initial trend toward MIS, these approaches involve more extensive dissection to gain access to the target organ via a myocutaneous flap.

Currently, transaxillary, bilateral axillo-breast approach (BABA), retroauricular facelift, and transoral approaches are the most commonly performed techniques. Both endoscopic and robotic approaches are being utilized, but over time, robotic surgeries are being performed more frequently due to the proposed advantages of enhanced visualization and maneuverability while working in a constrained work space. Of note, da Vinci robotic (Sunnyvale, California) thyroid and parathyroid surgeries remain off-label use in the United States.

Over the last two decades, numerous peer-reviewed papers have been published validating the safety and efficacy of various remote access approaches for both benign and malignant diseases of thyroid and parathyroid. Especially for the transaxillary and BABA robotic approaches,

long-term follow-up outcomes on advanced thyroid cancer patients and reports of modified radical neck dissections are being published.^{1,2}

HISTORY OF ENDOSCOPIC/REMOTE-ACCESS ENDOCRINE SURGERY

Cervical endoscopic thyroidectomies were initially reported by Huscher et al. in 1997 followed by Inabnet and Gagner in 2001.^{3,4} This concept was eventually adapted and popularized by Miccoli as minimally invasive video-assisted thyroidectomy (MIVAT).⁵ Initial reports of remote-access surgeries were from Japan where Ikeda and Shimazu introduced the first transaxillary endoscopic thyroidectomy in 2000 and endoscopic axillo-bilateral breast approach (ABBA) in 2003, respectively.^{6,7} Similar endeavors were also made in South Korea. Starting in 2001, Chung and colleagues at the Yonsei University in Seoul adopted two major changes that have led to a modern-day transaxillary surgical approach: a fixed-retractor for the skin flap for a gasless exposure, and implementation of da Vinci robotic system.⁸ Similarly, in 2004, Youn and colleagues at the Seoul National University in Seoul, Korea have developed the BABA robotic surgery utilizing four widespread instrument trocars for optimal triangulation and midline view of the target organ.⁹

Then in the United States, retroauricular or facelift thyroidectomy was introduced by Terris and Singer in 2010, where a single hidden incision is made along the postauricular crease and occipital hairline for a shorter flap distance to the target organ.¹⁰

Two techniques of transoral endoscopic thyroidectomies have been described, the sublingual and vestibular

approaches. The sublingual approach was first described in 2007 followed by varying successes with animal and, subsequently, human trials.¹¹ In 2015, Dr. Anuwong from Bangkok, Thailand, described the largest human series of transoral endoscopic thyroidectomy vestibular approach (TOETVA), where the incisions are made inside the lower lip instead of the floor of the mouth, as in the sublingual approach.¹²

PRINCIPLES AND TECHNIQUE

General surgical principles of thyroid and parathyroid surgeries are maintained in remote-access surgeries for a safe and sound oncologic outcome. Based on the more recent reported series from high-volume centers, surgical completeness as well as complication rates for the recurrent laryngeal nerve (RLN) injury, hypoparathyroidism, and neck hematoma are equivalent between the conventional and remote-access techniques. Certain initial reports of higher transient vocal cord and hypoparathyroidism complications may be attributed to differences in the routine postoperative screening method as well as the steep learning curve associated with these approaches.^{13–15} Complications related to myocutaneous flaps include bruising, postop seroma, paresthesia, and necrosis. Infection is extremely rare. In general, tense neck hematomas can pool along the flap space, decreasing the risk of airway compromise, and the interventions can be achieved via the same endoscopic incisions. Patient selection and indications may vary depending on the approach and institutions and should reflect the overall experience of the surgeon and the operating room staff.

TRANSAXILLARY APPROACH

Indication and preparation

Indications for transaxillary approach include well-differentiated thyroid cancer size ≤ 4 cm including lateral neck metastasis, benign or follicular neoplasm with size ≤ 5 cm, and Graves disease. Contraindications include preoperative evidence of tumor invasion to adjacent organs, such as trachea, recurrent laryngeal nerve, esophagus, and vessels. Partial or total thyroidectomy and central neck and lateral neck dissections can be performed via this approach.^{1,16}

Procedure

PATIENT POSITIONING

The patient is placed in a supine position with neck extension and ipsilateral arm forward flexion (**Figure 83.1**). Proper positioning of the arm is the key to a good exposure as well as prevention of brachial plexus injury often due to traction. An optimal incision site should be outlined while



Figure 83.1 Transaxillary thyroidectomy positioning with neck extension and ipsilateral arm forward flexion. The arm should be well-supported, and to avoid traction injuries to the brachial plexus, external shoulder rotation and lateral neck flexion should be minimized.

the patient is standing, just parallel to the posterior border of the pectoralis major but completely hidden when the arms are down in a natural position. In general, the inferior margin is determined by a transverse line from the supra-sternal notch. The superior margin is determined by drawing a 60°–70° angled line from the laryngeal prominence to the axilla (**Figure 83.2**).

MYOCUTANEOUS FLAP CREATION

A single 5–6 cm axillary incision is made. A subcutaneous flap is created superficial to the pectoralis major fascia along the clavicle using an electrocautery device under



Figure 83.2 Incision site (~6 cm length) and myocutaneous flap skin drawing. The incision is made along the anterior axillary line but should be marked while the patient is sitting upright for an optimal cosmetic outcome.



Figure 83.3 Myocutaneous flap retraction. Sternal head of the SCM and strap muscles are reflected anteriorly using a self-retraining bladed retractor to expose the thyroid gland and the great vessels.

direct visualization. Handheld retractors are utilized for this process. Once the sternoclavicular joint and the clavicular head of the sternocleidomastoid muscle (SCM) are localized, further dissection is carried out cephalad along the SCM. The sternal head of the SCM and omohyoid muscle are reflected down, while the clavicular head is lifted up to expose the underlying great vessels. These vessels are reflected ventrally. Then the sternohyoid and sternothyroid muscles are separated to expose the thyroid gland. Once the thyroid lobe is completely exposed past the isthmus, and adequate work space is acquired, a fixed retractor is secured to maintain the open myocutaneous flap (**Figure 83.3**).

DOCKING ROBOTIC INSTRUMENTS (FOR ROBOTIC APPROACH)

Through the relatively small axillary opening, four robotic arms are docked using a modified technique (camera, 8 mm ProGrasp, 5 mm Maryland, and Harmonic scalpel) to provide optimal visualization and maximum triangulation while minimizing the fighting between the arms (**Figure 83.4**).

THYROID (OR PARATHYROID) OPERATION

The camera and the instrument arms approach the target organ from a full lateral view. The thyroid gland is mobilized, and the recurrent laryngeal nerve as well as parathyroid glands are well visualized and preserved. A bedside assistant can provide retraction, suction, and irrigation as well as neuromonitoring through the skin opening. The general principle is to mobilize the thyroid gland anteriorly

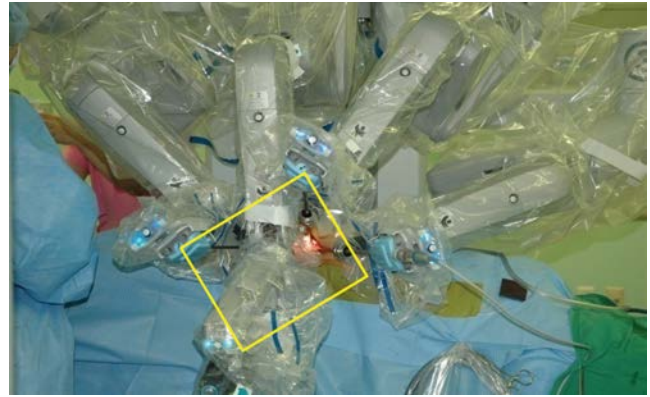


Figure 83.4 Transaxillary approach robotic (Si model shown) docking for a camera trocar and three instrument arms. Spatial separation is key to minimize fighting between the arms while maintaining ideal triangulation.

toward the ceiling to safely divide the Berry ligaments away from the RLN. Although the transaxillary approach is a unilateral approach, total thyroidectomy can be safely performed with appropriate maneuvers to visualize the contralateral RLN and parathyroid glands. A closed suction drain may be placed with a compression dressing to minimize seroma formation.

Postoperative management and outcome

Patients may be admitted for pain control and observation. In case of expanding hematoma, the axillary incision can be reopened for evacuation and endoscopic hemostasis. Otherwise, routine postoperative management is provided, similar to the conventional surgery.

FACELIFT THYROIDECTOMY APPROACH

Indication and preparation

Currently, the facelift approach is reserved for ipsilateral lobectomy with presumed benign nodules up to 4 cm. Given the less extensive tissue dissection for flap creation, the facelift approach is typically performed as an outpatient surgery.^{10,17,18}

Procedure

PATIENT POSITIONING

The patient is placed in a supine position with both arms down to the side and the head turned sideways.

FLAP CREATION AND TECHNIQUES

A single incision is made along the inferior margin of the ear lobule down to the postauricular crease and occipital hairline. Then a subplatysmal flap is created along the

SCM muscle using an electrocautery under direct visualization. Once the omohyoid and strap muscles are identified and retracted ventrally to expose the thyroid gland, a fixed retractor is placed to maintain a gasless exposure of the target organ, similar to the transaxillary approach. Docking is also similar in that four robotic arms are deployed through the skin opening in a modified technique to optimize the instrument maneuverability while minimizing collisions between the arms.

THYROID OR PARATHYROID OPERATION

Superior thyroid vessels are always dissected first in a top-down approach, and the RLN is identified near the insertion site. Medial dissection along the ligament of Berry is carried out while retracting the gland off the thyroid bed toward the lower pole, and the isthmus is divided at the end. An assistant can provide similar interventions as in the transaxillary approach through the flap opening. Drains are not routinely placed.

Postoperative management and outcome

Patients are routinely discharged home from the recovery room. Incisional scars are well hidden, especially for patients with long hair.

BILATERAL AXILLO-BREAST APPROACH

Indication and preparation

Currently, BABA robotic thyroidectomy is indicated for low-risk/well-differentiated thyroid carcinoma less than 5 cm, benign nodules less than 8 cm, and Graves disease with 150 mL.

Routine breast exam and mammograms are performed according to the risk-based guidelines. Prior breast cancer or reconstructive surgeries can be a relative contraindication for BABA. For patients with a small breast or a muscular chest wall, given the limited maneuverability of instruments, the robotic technique is preferred.^{2,19,20}

Procedure

PATIENT POSITIONING

The patient is in a supine position with a shoulder pillow for neck extension and exposure of anterior axillary skin folds. Skin markings are drawn based on the anatomic landmarks (**Figure 83.5**). A subcutaneous hydrodissection is performed along the flap area using 1:200,000 epinephrine solutions. Four trocars are utilized. Initially, two areolar incisions are made; a 12 mm curvilinear R. areolar incision for the camera and 5–8 mm L. areolar incision for the energy device to initiate the flap creation (**Figure 83.6**).

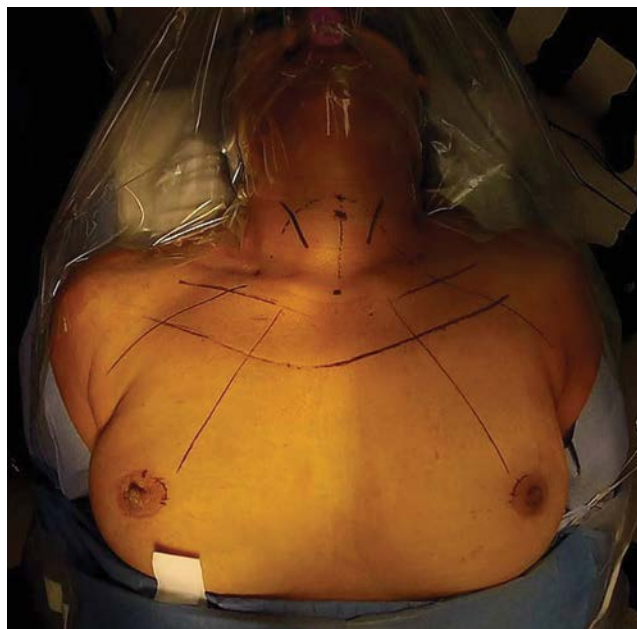


Figure 83.5 Bilateral axillo-breast approach thyroidectomy setup. Positioning is similar to the open thyroid surgery. Arms are resting at the sides and the neck is extended. Neck, chest, breast, and axilla are prepped and draped.

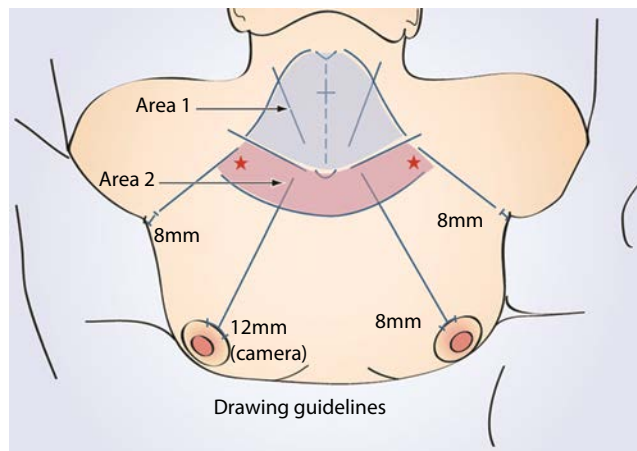


Figure 83.6 Incisions sites, trocar angle, and flap skin drawing. A wide angle is preserved between the instruments. An 8 mm camera trocar can be used and switched to the left breast depending on the desired view. Area 1 represents the usual subplatysmal flap superior to the sternal notch and clavicles. Area 2 represents the initial subcutaneous flap space for trocar insertion. One of the axillary incisions is utilized for specimen extraction.

FLAP CREATION AND TECHNIQUES

Through the bilateral areolar incisions, a blunt dissection is performed along the subcutaneous plane using a straight clamp followed by a blunt vascular tunneler. Mammary glandular tissues are preserved. Once the bilateral areolar

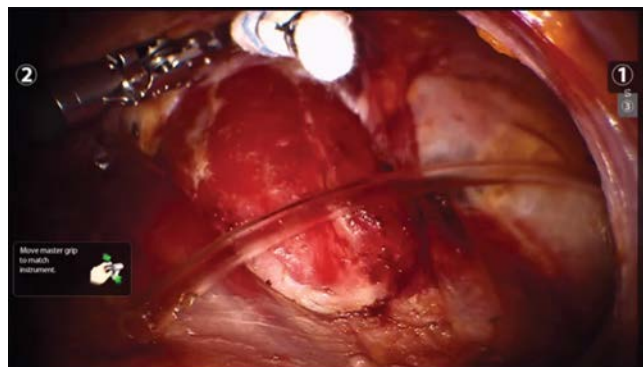


Figure 83.7 Completed subplatysmal flap with visualization of midline, strap muscles, and bilateral sternocleidomastoid muscles. Suction irrigation catheter and Kittner sponges can be utilized.

cannulas are in confluence under the flap, sharp dissection is carried out under direct visualization for the remainder of the subplatysma flap creation and bilateral axillary cannula insertion. Low-pressure (6 mm Hg) insufflation maintains the flap space, the robotic arms are docked with an ideal separation between each arm, and the midline view is achieved of the bilateral strap and sternocleidomastoid muscles (**Figure 83.7**).

THYROID OR PARATHYROID OPERATION

The strap muscles are divided at the midline exposing the isthmus. Then the isthmus is divided where the cut-end is grasped and retracted medially for the lateral dissection down to the carotid sheath. With ongoing medial retraction, the recurrent laryngeal nerve is localized (**Figure 83.8**). Neuromonitoring is routinely performed

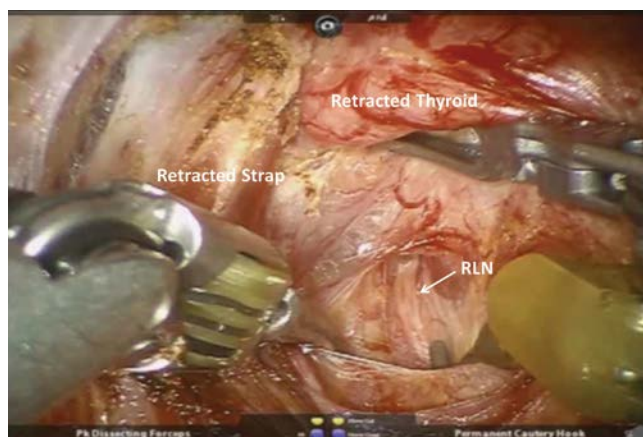


Figure 83.8 Nerve dissection. The thyroid gland is retracted medially with a grasper, and strap muscles are retracted laterally with a dissector to visualize the nerve. Hook cautery can be used as a nerve stimulator instead of a monopolar cautery by connecting to a nerve monitoring device.

using the robotic hook cautery via a modified connection. Once the nerve and the inferior parathyroid gland are identified, the thyroid gland is mobilized starting from the lower pole of the thyroid toward the Berry ligament. Finally, upper pole vessels are isolated and divided using an energy device. Throughout the surgery, traction and countertraction are provided via the two opposing axillary instruments. Contralateral lobectomy is performed in a similar manner. A bedside assistant can help with irrigation and suction using a catheter inserted through the axillary cannula site. Specimen is removed through the axilla in an endoscopic bag. Drains can be placed as needed.

Postoperative management and outcome

Patients are routinely admitted for observation and pain control. In case of a tense hematoma, endoscopic evacuation and intervention can be performed via the trocar sites. A compression dressing is applied over the breast and upper chest for several days to minimize the risk of seroma formation.

TRANSORAL APPROACH

Indication and preparation

Limited publications exist on TOETVA and other transoral techniques. Based on the study with the largest series, indications include multinodular goiter, benign nodule, Graves disease, and papillary microcarcinoma. As a clean-contaminated case, the oral cavity is disinfected with 0.05% Hibitane solution preoperatively along with prophylactic IV antibiotics. Dental examination may be warranted.^{12,21}

Procedure

PATIENT POSITIONING

The patient is placed on a thyroid pillow with neck extension. A midline transverse 10 mm incision is made at the oral vestibule followed by two 5 mm lateral incisions on both sides between the incisor and canine. Three trocars are utilized. Using a needle injection, a hydrodissection is performed with diluted epinephrine solution (1:500,000) along the vestibule and anterior neck (**Figure 83.9**).

FLAP CREATION AND TECHNIQUES

Initially a blunt dissection is performed with a Kelly clamp through the 10 mm incision, which is then further extended using a blunt tip rod-dissector along the subplatysma plane. The flap is insufflated with 6 mm Hg, and the two 5 mm trocars are inserted. Particular attention is made to minimize injuries to the mental nerve during this process. Additional dissection is performed along the anterior neck under the

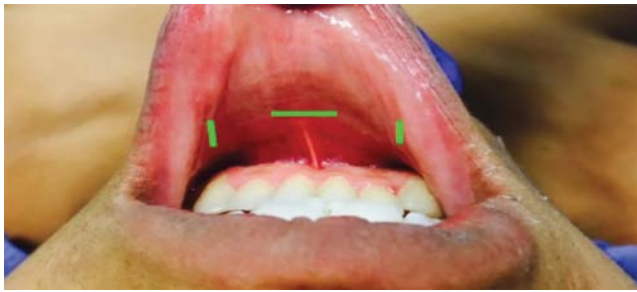


Figure 83.9 Incision sites for transoral thyroidectomy. About 1.5 cm transverse incision is made near the base of the frenulum for camera and specimen extraction. Two 5 mm antero-lateral vertical incisions are made along the incisors in an effort to minimize mental nerve injuries.



Figure 83.10 Following the blunt dissection through the mentalis muscle into the subplatysmal flap, a 12 mm optical trocar is inserted. Then two 5 mm trocars are inserted into the flap space under direct visualization.

direct visualization with an energy device. Similar to the BABA approach, TOEVA gives a midline view of the neck with top-down orientation (**Figure 83.10**).

THYROID OR PARATHYROID OPERATION

The strap muscles are opened at the midline and the exposed isthmus is divided. The superior pole of the thyroid gland is dissected in a top-down approach, and the superior pole vessels are divided using an energy device. The gland is then retracted with medial rotation to expose the RLN insertion site. Nerve monitoring can be performed using a standard laparoscopic instrument with a modified connection. With careful attention around the Berry ligament, the RLN and parathyroid glands are preserved (**Figure 83.11**). The lateral retraction of strap muscles can be facilitated by a percutaneous suture under an external tension. The specimen is

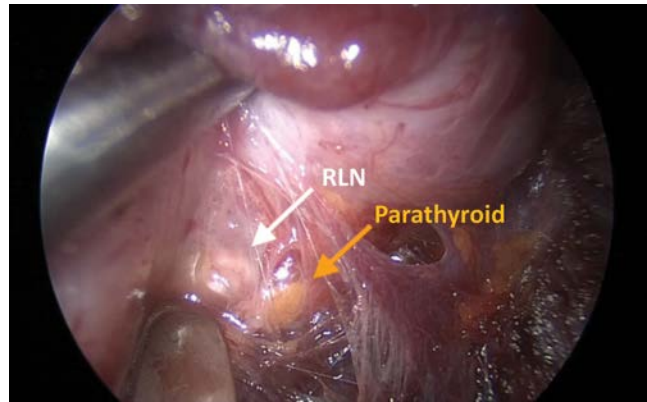


Figure 83.11 Top-down dissection of the thyroid gland is performed where the recurrent laryngeal nerve is localized near the insertion site once the superior thyroidal vessels are divided. The nerve is dissected inferiorly with medial traction of the thyroid gland. Parathyroid glands are well visualized and preserved.

removed in an endoscopic bag, and to facilitate the extraction through a narrow tunnel over the mental protuberance, the specimen may need to be divided carefully in the endoscopic bag. Drains can be placed through a separate cervical incision as needed.

POSTOPERATIVE MANAGEMENT AND OUTCOME

Patients are routinely admitted for observation and pain control. Tense hematoma may require cervical incision for an appropriate intervention. Compression dressing is applied under the chin for a day. Perioperative antibiotics are continued for several days.

CONCLUSION

Remote-access surgery for thyroid and parathyroid is continually evolving and gradually establishing its role in endocrine surgery. Different approaches are being introduced and offered at a few selective centers with much enthusiasm and optimism. The innate and unique challenges related to the remote access surgeries, such as the myocutaneous flap, constrained work space, altered orientation, and the steep learning curve, should be continually assessed and reconciled to promote an appropriate standard. For a selective group of patients who are motivated in avoiding conspicuous neck scars, these remote-access surgeries may confer great cosmetic and confidentiality benefits. Particularly, remote-access neck dissection may confer the greatest cosmetic benefit for patients, given the alternative. Regardless of the surgical approach, maintaining the key surgical principles along with careful patient selection is paramount for safe and sound oncologic outcomes for the patients.

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Laparoscopic resection of endocrine pancreatic neoplasms

CHERIF BOUTROS AND JOHN A. OLSON JR.

INCIDENCE AND BIOLOGIC SPECIFICITY

Pancreatic neuroendocrine tumors (PNETs) are a group of heterogeneous neoplasms with variable biologic behavior. The annual incidence of PNET is 0.1 ± 0.4 per 100,000.^{1,2} PNETs are classified clinically as functional, secreting hormones responsible for clinical syndromes (e.g., gastrinoma, insulinoma), or nonfunctional. Pathologically, PNETs are classified according to their size, presence of lymph node or distant metastasis (TNM classification), or more commonly according to their degree of differentiation (World Health Organization [WHO] classification) (Table 84.1).³ From the technical point of view, the number and location of PNETs will dictate the therapeutic strategy and operative technique, including enucleation, distal-subtotal pancreatectomy or pancreaticoduodenectomy.

INDICATIONS OF SURGICAL RESECTIONS AND ONCOLOGIC GOALS

PNETs have complex patterns of behavior requiring detailed specialist management. Surgery remains the only curative modality currently available for resectable PNETs.⁴ For

nonfunctional PNETs, there is a generalized consensus that a tumor size of 2 cm is used as a cutoff to predict malignant behavior warranting surgical resection. For these tumors, the National Comprehensive Cancer Network guidelines recommend tumor resection with regional lymph node dissection. For tumors less than 2 cm, the surgical technique is less clear, and surgical options include local resection by enucleation with or without lymphadenectomy. The concept of enucleation was recently challenged in a retrospective study of the National Cancer Database. In this study, lymph node metastasis was found in 24%–67% of PNETs less than 2 cm.⁵ In patients with metastatic disease, deciding whether resection of the primary tumor is appropriate should be based on the ability to resect the metastatic disease, the presence of clinical symptoms, and the PNET location. In the absence of a symptomatic primary tumor with unresectable extrapancreatic metastasis, surgical resection of the primary tumor is generally not indicated. However, in selected patients with localized hepatic metastasis, combined resection of the primary tumor and liver metastases should be attempted and is associated with improved survival.⁶

ROLE OF MINIMALLY INVASIVE SURGERY

The goal of surgery for a PNET is to remove the entire tumor (complete, R0 resection), lymph nodes at risk for metastasis, and resectable metastatic disease, if present. The approach (open or laparoscopic) is less important than achieving a safe, R0 resection. However, with appropriate expertise, a minimally invasive approach is favored. The main advantages of the minimally invasive approach are less operative blood loss, length of stay, postoperative pain, use of narcotics, and early recovery. Moreover, the minimally invasive

Table 84.1 2010 WHO classification of gastrointestinal-pancreatic neuroendocrine tumors

	Mitosis per high power field and/or percentage (%)	Ki-67 index (%)
Grade 1	2–10	≤2
Grade 2	10–20	3–20
Grade 3	>20	>20

approach can expand surgical indications to borderline patients otherwise considered poor surgical candidates.

MINIMALLY INVASIVE DISTAL PANCREATECTOMY

First reported in 1996 by Gagner⁷ and Cuscheiri,⁸ laparoscopic distal pancreatectomy (LDP) has gained rapid popularity. All series report less blood loss and shorter length of stay when comparing LDP to the traditional open approach. Another reported advantage of laparoscopic exploration is avoiding unnecessary laparotomy to 10%–38% of patients due to intraoperative findings of metastatic disease otherwise unidentified in preoperative imaging.^{9,10} After the first 5 years of its introduction, a series of LDP became more mature, included a larger number of patients with procedures performed by experienced teams after a “reasonable” learning curve. Over a 10-year period from 2001 to 2011, 25 studies

of LDP each including more than 10 patients were published in English reporting 829 procedures (Table 84.2). Analysis of these studies revealed an average morbidity of 37.6%. The pancreatic fistula rate was 19.8%, reoperation 3.7%, mortality 0.2%, and hospital length of stay was 6.6 days. Ten percent of these procedures were performed for neuroendocrine tumors. When compared to open distal pancreatectomy, LDP was associated with less blood loss, less morbidity and mortality, shorter length of stay by 4 days, and earlier by mouth intake on postoperative day 2 with no significant change in the operative time.¹¹ These advantages are still valid for nonselected patients.¹² A meta-analysis of 11 studies (906 patients) of PNETs, of whom 203 (22%) underwent laparoscopic resection and 703 (78%) underwent open pancreatectomy, reported the same advantage of the laparoscopic approach. In the study, the vast majority of the laparoscopic procedures were either LDP or enucleation. Laparoscopic pancreatic surgery (LPS) was associated with a lower overall complication rate (38% in LPS versus 46% in open pancreatic surgery; $p < 0.001$). Blood loss

Table 84.2 Studies published in English reporting greater than 10 patients of LDP (2001–2011)

Author	Year	Journal	<i>n</i>
Patterson et al.	2001	<i>Journal of the American College of Surgeons</i>	15
Fabre et al.	2002	<i>Surgical Endoscopy</i>	13
Park et al.	2002	<i>Annals of Surgery</i>	23
Edwin et al.	2004	<i>Surgical Endoscopy</i>	17
Ayav et al.	2005	<i>Langenbecks Archives of Surgery</i>	15
Velnovich et al.	2005	<i>Journal of Gastrointestinal Surgery</i>	15
Dulucq et al. ²⁵	2005	<i>Surgical Endoscopy</i>	21
Mabrut et al.	2005	<i>Surgery</i>	24
Maburt et al.	2005	<i>Surgery</i>	98
Velnaovich et al.	2006	<i>Surgical Endoscopy</i>	11
Corcione et al.	2006	<i>Surgical Endoscopy</i>	14
D'Angelica et al.	2006	<i>Surgical Endoscopy</i>	16
Teh et al.	2007	<i>Journal of Gastrointestinal Surgery</i>	12
Pierce et al.	2007	<i>Surgical Endoscopy</i>	18
Fernandez Cruz et al.	2007	<i>Journal of Gastrointestinal Surgery</i>	20
Melotti et al.	2007	<i>Annals of Surgery</i>	58
Fernandez-Cruz et al.	2007	<i>Journal of Gastrointestinal Surgery</i>	72
Matsumoto et al.	2008	<i>Surgical Laparoscopy, Endoscopy, and Percutaneous Techniques</i>	14
Eom et al.	2008	<i>Surgical Endoscopy</i>	31
Burzonni et al.	2008	<i>Journal of Gastrointestinal Surgery</i>	74
Kim et al.	2008	<i>Surgical Endoscopy</i>	93
Kooby et al.	2008	<i>Annals of Surgery</i>	142
Nakamura et al.	2009	<i>HPB</i>	21
Kooby et al.	2010	<i>Journal of the American College of Surgeons</i>	23
Reeh et al.	2011	<i>World Journal of Surgery</i>	18
Total 25			Total = 878 ^a –829 Procedures

^a Some patients were included in more than one study.

and length of stay were lower in LPS by 67 mL ($p < 0.001$) and 5 days ($p < 0.001$), respectively. There were no differences in rates of pancreatic fistula, operative time, or mortality.¹³

Another important benefit of LDP is the higher rate of splenic-preserving surgery. Spleen-preserving distal pancreatectomy with splenic artery and vein resection (Warshaw procedure) in which the spleen is vascularized through short gastric vessels¹⁴ is associated with decreased overall morbidity, fewer intra-abdominal abscesses, lower operative blood loss, and shorter length of hospital stay compared to distal pancreatectomy with splenectomy.^{15,16} However, the Warshaw procedure is associated with a 20% rate of splenic infarction that may require interval splenectomy in patients who subsequently developed splenic abscess not manageable by interventional radiology drainage.¹⁷ The alternative spleen-preserving approach, distal pancreatectomy with preservation of splenic vessels, is a more technically demanding procedure. In experienced hands it can only be achieved in 50% of patients undergoing LDP.¹²

Recently a retrospective study compared results of 73 LDP versus 98 open distal pancreatectomy for PNETs.¹⁸ On multivariable analysis, method of resection (LDP versus open distal pancreatectomy) was not associated with survival difference. In a study focusing on cost comparison of open and LDP, the global cost including cost of readmission was found to be significantly less in the LDP group \$11,110 versus \$14,400.¹⁹

As per early adoption of a reproducible technique of LDP by different pancreatic surgery centers, robotic distal pancreatectomy (RDP) had less to add. In our opinion, RDP can be used to facilitate minimally invasive distal pancreatectomy for nonlaparoscopic trained surgeons and may have a role in the preservation of the splenic artery. However, these benefits need to be weighed against the cost of the robotic equipment.

Technical aspects

Our technique of LDP with splenic preservation has been previously reported.¹² After induction of general anesthesia

and placement of an orogastric tube and urinary catheter, the patient is positioned supine with both lower extremities in stirrups. This *French position* allows easy and ergonomic access for the surgeon to the operative field. Pneumoperitoneum to 15 mm Hg is established through a left subcostal Veress needle or infraumbilical Hasson trocar, and two 5 mm trocars are placed in the left and right upper quadrants in addition to the 12 mm trocar in the infraumbilical position. The abdominal cavity is then carefully explored laparoscopically to assess for the presence of metastatic disease. The gastrosplenic ligament is divided by an energy-based cutting and sealing device. It is important to preserve the short gastric vessels as an alternative splenic blood supply in case the main splenic vessels were found to be closely involved with the pancreatic tumor and need to be divided. The stomach is retracted superiorly and to the right and held in this position using a U 0/3 Nylon Keith needle stitch passed percutaneously and held at the skin level using a Halsted. At this point, it is important to use laparoscopic ultrasound to confirm the location of the PNET and its relationship to the pancreatic parenchyma and the pancreatic duct as well to the splenic vessels. Exophytic small PNETs with minimal attachment to the pancreas can be managed by enucleation or a parenchymal preserving strategy (**Figure 84.1**). For a distal or subtotal pancreatectomy, the dissection starts along the inferior border of the pancreatic body using electrocautery. The plane is developed laterally using a combination of blunt dissection and an energy-based sealing and cutting device, and medially as needed. Medially, great care is needed to avoid injury of the superior mesenteric vein. This dissection allows for the exposure of the inferior and posterior aspect of the pancreas and identification of the splenic vein that can now be dissected with all branches to the pancreas, divided between surgical clips or using the energy sealing and cutting device. Along the superior border of the pancreas, the splenic artery is easily identified and is dissected using a Maryland dissector and energy-based sealing device from the pancreas, and again, small branches can be individually dissected and divided between surgical

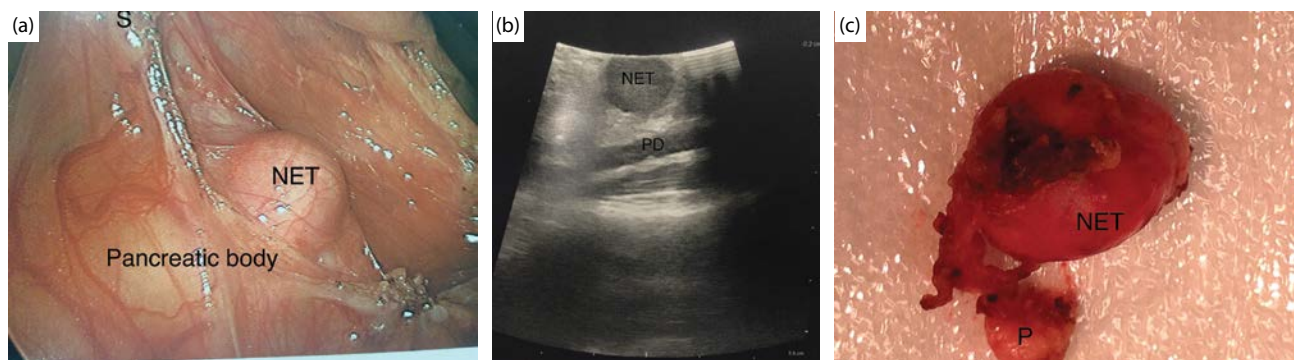


Figure 84.1 Laparoscopic resection of PNET at the body of the pancreas. (a) Laparoscopic picture of PNET of the pancreatic body. (b) Laparoscopic ultrasound to assess the relation of the PNET to the main pancreatic duct (PD). (c) Resected PNET with a rim of pancreatic tissue to assure complete resection.

clips. It is very important to include all lymph nodes along the splenic vessels in the resected specimen. At this point, with ultrasound guidance to ensure tumor clearance, the pancreas is divided using an endomechanical stapler with 2.5 mm (vascular) load proximal to the PNET. The specimen is placed in an endobag that will be extracted through the extended infraumbilical trocar. A drain is always placed near the pancreas remnant staple line to monitor for leak.

Postoperative care

Following routine LDP, the patient is monitored for at least 24 hours. A nasogastric tube is not usually needed and PO intake is often allowed on the same operative day. Blood sugar is checked using fingerstick Q6 hours. Prophylaxis against deep venous thrombosis is achieved with low molecular weight heparin. The typical length of stay is 1–3 days.

MINIMALLY INVASIVE PANCREATICODUODENECTOMY

Although laparoscopic pancreaticoduodenectomy (LPD) was initially reported in 1994,²⁰ 2 years before LDP, many fewer series discussed the role and the results of LPD. The reasons for this comparative are understandable: dissection in LDP is relatively easier, the technique is similar to the open approach, and there is no reconstruction of the hepatopancreato-biliary system required. A review of 285 patients from different published series who underwent LPD²¹ over a 17-year period included only four studies including more than 25 patients. The low number of highly selected patients limits our ability to meaningfully analyze the results of this approach and showed clearly that it has not gained popularity. Nevertheless, the results of these four studies ($n = 166$) revealed a mean operative time of 340 minutes, blood loss of 180 mL, mortality rate of 2%, and mean length of stay (reported only in two studies) of 7 and 19 days. It was obvious

from these data that only a few centers were able to adopt this technique for highly selected patients. Most recently, a single study reported a series of 100 consecutive LPD, one of the largest series to date.²² Importantly, this study discussed the learning curve for LPD, a significant concern for the adoption of this uncommon procedure across a number of centers. In this series the complication rate decreased from 33.3% for the first 33 cases to 17.6% for the last 34 cases. Similarly, operative time decreased from 9.8 hours to 6.6 hours, respectively. The mean hospital stay was 14 days, which also decreased from 20.4 days for the first 33 cases to 11.5 days for the last 34 cases.

A retrospective comparison study between open ($n = 215$) and LPD ($n = 35$) was published from Mayo clinic.²³ In this study operative blood loss, ICU length of stay, and overall hospital stay were significantly less in the LPD group (195 mL versus 1000 mL, 8 days versus 12 days, 10 days versus 34 days, respectively). At the same time, operative time was significantly longer in the LPD group (541 minutes versus 401 minutes). Among malignant cases, tumor size was similar, and the number of retrieved LN was higher in the LPD group (23 versus 16). One year later, the Mayo clinic group published a cost analysis study comparing the two groups.²⁴ The study showed that the LPD group was associated with significantly higher surgical cost due to both increased time and supply cost. However, mean hospital admission cost associated with the open approach was greater in comparison to the LPD group. The overall total cost of care was similar between the two groups.

Results of published LPD studies including more than 25 patients are summarized in [Table 84.3](#).

As described, LPD, secondary to its technical complexity, failed to be adopted by most of the pancreatic surgery centers. The need for a better minimally invasive approach facilitated the introduction of robotic pancreaticoduodenectomy (RPD). Initial experience is well reported in two studies that included more than 50 patients.^{34,35} with conversion rate of 31%, operative time 487 minutes, operative blood loss 327 mL, pancreatic fistula rate 31%–22%, hospital length of stay (22, 10 days) and mortality rate of 2%.

Table 84.3 Published LPD studies including more than 25

Study	<i>n</i>	Operating room time median (minutes)	Estimated blood loss median (mL)	Length of stay (days)	Mortality
Dulucq ²⁵	25 (1 PNET)	287	107	16.2	1
Gumbs ²⁶	35	360	300	NR	NR
Palanivelu ²⁷	75 (No PNET)	357	74	8.2	1
Kendrick ²⁸	65 (4 PNET)	368	240	7.2	1
Asbun ²³	53 (6 PNET)	541	195	8	3
Kim ²²	100 (15 PNET)	487	NR	15	NR
Croome ²⁹	108 (no PNET)	379	492	6	1
Senthilnathan ³⁰	130	310	110	8	2
Wang ³¹	31 (no PNET)	515	260	12.6	0
Dokmak ³²	46 (13 PNET)	342 (mean)	368 (mean)	25 (mean)	2
Paniccia ³³	30 (1 PNET)	340	300	11	0

Abbreviations: NR, not reported; PNET, pancreatic neuroendocrine tumor.

Most recently, a single institution review of robotic pancreatic surgery from Pittsburgh³⁶ included the largest number of RPD patients ($n = 132$). In this study, operative time was 527 minutes $\pm$ 103, and conversion rate was 8.3% and reoperation rate was 3%. The mean length of hospital stay was 10 days with readmission rate of 28%.

It is clear that LPD has failed to be adopted in most surgical centers, likely due to the complexity of the procedure and the reconstructive phase. RPD is gaining rapid popularity in high-volume pancreatic surgery centers by highly specialized surgeons. Three points need to be emphasized: (1) First, all of these reports of RPD showed the feasibility and safety of this new technology but failed to clearly improve the outcome of this complex procedure compared to the traditional open approach. Second, selection criteria of candidate patients for RPD need to be better defined and should include more factors beyond body mass index and previous abdominal surgery, as pancreatic and bile duct size. Third, the extensive learning curve for this complex procedure limits its application in most of the pancreatic surgery centers. A more simplified technique needs to be created to make RPD a reproducible procedure. It is possible that a hybrid approach with laparoscopic, robotic, and open components is a good model to start the integration of RPD in different pancreatic surgery centers.

We have experience with a hybrid approach (Figure 84.2), in which an exploration of the abdominal cavity and determination of resectability are performed laparoscopically. We have found that dissecting the pancreatic neck from the portal vein and development of the tunnel between the superior mesenteric vein and pancreas, cholecystectomy, kocherization of the duodenum, division of proximal jejunum and distal stomach, and decrossing of the duodenum from the root of the mesentery may all be completed laparoscopically with ease. These steps are usually straightforward for an experienced laparoscopic surgeon and can be achieved in timely fashion compared to the robotic technique. There is no need to change robotic docking position or camera position, and a larger field of camera vision is obtained. Following the laparoscopic mobilization, robotic dissection of elements of the hepatoduodenal ligament is performed with dissection and division of the common bile duct, dissection of the hepatic artery, and division of the gastroduodenal artery. Pancreaticobiliary and enteric reconstruction can be performed robotically assisted in the case of large pancreatic duct and firm pancreatic parenchyma or by open approach through a 6 cm mini laparotomy centered over the pancreatic neck that is used for specimen extraction.

In summary, a PNET with its relative indolent character and small size present an excellent application for a pancreatic minimally invasive approach. Multiple studies showed that minimally invasive pancreatic surgery achieves similar oncologic results to traditional open resection. It is clear for us that LDP for PNET located in the left pancreas is rather the standard than the exception. Similarly, parenchymal preserving strategy (enucleation)

when compared to traditional resections, had shorter hospital stays with no differences in morbidity, mortality, or survival.³⁷ Techniques of minimally invasive pancreaticoduodenectomy, though well reported, are in evolution. The role of robotic surgery and its potential addition to the feasibility and safety of LPD is to be emphasized. The

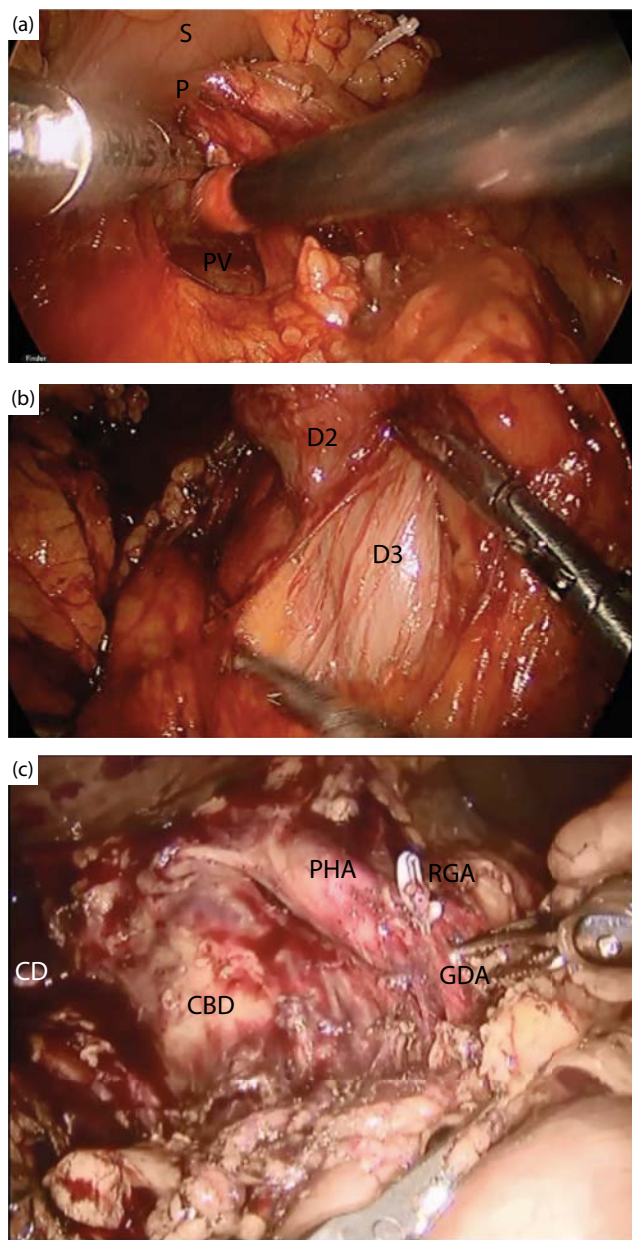


Figure 84.2 Hybrid approach for LPD. (a) Laparoscopic dissection of the superior mesenteric vein–portal vein (PV) junction from the pancreatic neck (P) in the lesser sac with a retracted stomach (S). (b) Laparoscopic mobilization of the second and third duodenum (D2–D3) by blunt dissection in the avascular plan. (c) Robotic dissection of the hepatoduodenal ligament with control of the common bile duct (CBD), proper hepatic artery (PHA) after ligation and division of the right gastric artery (RGA) and cystic duct (CD), and dissection of the gastroduodenal artery (GDA).

long learning curve is a major barrier to adopting a full robotic strategy. A hybrid approach seems a more realistic, safe, and reproducible achievement for minimally invasive pancreaticoduodenectomy.

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Minimally invasive approach to disease of the gastrointestinal tract



Christian Schäd, *The Operation*, 1929. Oil on canvas, 49 x 37 1/2 inches. Städtische Galerie im Lenbachhaus, Munich. (Photo courtesy Lenbachhaus. © 2018 Christian Schäd Stiftung Aschaffenburg / ARS, New York / VG Bild-Kunst, Bonn.)

After observing an appendectomy, Christian Schad described his experience: “Someone put a white coat on me and I was able to watch the removal of an appendix from close up. After fourteen minutes, when the operation was over and we had taken our white coats off, the surgeon said, ‘Right then, now we’ll go dancing again.’ But, I didn’t go with him. I went straight home and started to sketch. It was the almost mathematically accurate interplay of action and interaction that had fascinated me, the concentrated life of the procedure, which ran wordlessly with the precision of clockwork.” His response is evoked in this painting. The precision and intense focus of the process—completed in “fourteen minutes”—is reflected in the way the scene is rendered with great detail, along with the intense focus of the medical team as the surgeon extracts the appendix. Schad also reported that the procedure had run “wordlessly:” while united in their physical task, which they perform perfectly, the team does not look at one another or interact psychologically in any way. The sterility of the scene borders on

overwhelming: everyone but one nurse is dressed fully in white; the white bed sheet almost completely encases the patient’s body; the numerous surgical instruments shine brightly, as if they had not been used; and there is almost no blood. The lack of visible blood caught the attention of the surgeon, who came to Schad’s studio. The artist reported, “he brought his instruments with him and gave me advice from the point of view of a surgeon. Once he pointed out that the color of the intestines in my painting was too pallid.” The nurse anesthetist at the head of the patient was modeled by the artist’s girlfriend, while the patient was his friend Felix Bryk, an entomologist and ethnographer.

Quotes from Jill Lloyd and Michael Peppiatt, eds., Christian Schad and the Neue Sachlichkeit (New York: W. W. Norton, 2003), 233. Text by Mariann Smith, courtesy Center for Medical Humanities, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo.

Laparoscopic treatment of diseases of the small bowel

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INTRODUCTION

Laparoscopic management of small bowel diseases is more common as minimally invasive techniques have become more prevalent over the last decade. Historically, the role of laparoscopy in small bowel disease was limited due to inadequate preoperative localization of small intestine lesions and the lack of tactile feedback during laparoscopy. However, with advanced surgical devices and improvements in endoscopy and radiologic localization, laparoscopy is now a therapeutic modality for complex diseases of the small intestine.

ABDOMINAL ACCESS

There are multiple techniques to access the abdominal cavity during laparoscopy. The Hassan technique is usually the safest, as it directly visualizes the underlying intra-abdominal structures. This technique involves an infraumbilical midline incision with dissection of the subcutaneous fat to the level of the abdominal rectus fascia, and incision of the umbilical raphe. Some surgeons prefer a Veress needle technique away from the midline due to previous surgery and suspected adhesions. Palmer point is often used as the Veress needle insertion site, which is located 3 cm, or 2 fingerbreadths, below the left costal margin in the midclavicular line. The stomach should be decompressed with a nasogastric or orogastric tube prior to inserting the Veress needle. Once a sufficient pneumoperitoneum has been achieved, a 5 mm, 0° scope inserted through a 5 mm visual trocar can be used to enter the abdomen layer by layer. Another option is a direct cut down in any location of the abdomen. This may be the preferred approach in patients with diffusely distended bowel secondary to a small bowel

obstruction (SBO) since the Veress technique may increase the likelihood for bowel perforation.

Once the initial trocar is placed, subsequent trocars are placed based on the intra-abdominal findings. A minimum of three ports, including the camera port, are required to adequately run the bowel. Examining the small bowel may be achieved from any quadrant, and trocar placement should focus on a central viewing port with triangulation of the two additional ports. In general, the terminal ileum is easier to identify, so the bowel is usually examined distally and then followed to the ligament of Treitz. However, if the small bowel pathology is known to be in the proximal bowel, starting at the ligament of Treitz avoids manipulating and injuring the distal bowel.

SMALL BOWEL OBSTRUCTION

An estimated 300,000 patients are hospitalized annually with SBO in the United States, with 75% attributed to post-operative adhesions.¹ Other common causes of SBO include neoplasms, hernias, and Crohn disease. Complications of SBO remain high with an incidence reaching 30% for strangulation and 15% for bowel necrosis.¹ A SBO is diagnosed with a focused history, physical exam, and imaging, usually with an abdominal series or a computed tomography (CT) scan. However, a CT scan does not need to be routinely performed in all patients with SBO, but can confirm a complete obstruction, rule out nonadhesive pathology, and evaluate ischemic bowel.² If the patient is hemodynamically stable and has no signs of peritonitis, nonoperative management is usually the initial treatment with resuscitation and a nasogastric tube. A small bowel follow-through with water-soluble contrast can predict nonoperative resolution of SBO if contrast reaches the colon within 24 hours.²

However, patients who are hemodynamically unstable, have signs of peritonitis, or have evidence of ischemic bowel on CT should undergo operative intervention. Although non-specific, indicators of ischemia include fever, tachycardia, and elevated white blood cell counts and lactate levels.

In cases of strangulation and ischemia, most surgeons would advocate for a laparotomy due to the hemodynamic effects of ischemic bowel and the diffusely distended bowel that may prevent laparoscopic access. In patients who fail to respond to nonoperative management, a laparoscopic approach can be employed in select patients. Laparoscopic surgery usually succeeds in patients with the first episode of SBO, and in those patients with single-band adhesive disease. A direct cut-down in the left upper quadrant for trocar placement is the preferred access site. If extensive, dense adhesions are found, a low threshold for a laparotomy should be considered. Laparoscopic shears should be used without electrocautery for adhesiolysis of adhesive bands near bowel. The dilated proximal bowel must be handled gently, and electrocautery and ultrasonic devices should be used sparingly.

In one review of over 2,000 laparoscopic surgical cases for SBO, 64% were treated successfully with laparoscopy, 6.7% were lap-assisted, 0.3% were converted to hernia repair, and 29% were converted to midline laparotomy. The majority of conversions were due to dense adhesions, need for bowel resection, unidentified etiology, and iatrogenic injury.³ Similarly, another study demonstrated that one-third of patients presenting with an SBO were not amenable to laparoscopy due to hemodynamic instability, massive distention, and multiple laparotomies. Of the two-thirds who underwent laparoscopic surgery, one-third required conversion to an open approach secondary to massive distention; a retroperitoneal or pelvic pathology; difficult adhesiolysis; or a contracted, thickened mesentery from neoplasms or Crohn disease.⁴ Although the conversion rates appear high, laparoscopic treatment of SBO has numerous advantages as compared to the open approach. These are similar to other laparoscopic surgeries and include less postoperative pain, faster return of bowel function, shorter length of stay, reduced recovery time, decreased wound complications, and decreased adhesion formation.^{5,6}

INTESTINAL NEOPLASMS

Neoplasms of the small intestine are rare, comprising only 2.8% of all gastrointestinal cancers. Signs and symptoms are usually nonspecific and may include abdominal pain, nausea, vomiting, weight loss, occult bleeding, obstruction, or perforation. Furthermore, diagnosing neoplasms outside of the duodenum, proximal jejunum, and terminal ileum is difficult due to the lack of visualization and ability to obtain a biopsy if needed. Subsequently, a diagnosis for these occult tumors is often delayed. However, advances in endoscopy, including single- and double-balloon endoscopy (push enteroscopy), may visualize neoplasms beyond the normal

reach of standard enteroscopes. These new technologies can also tattoo distal lesions, and enhance laparoscopic identification of intraluminal neoplasms. Laparoscopic resection can be performed using laparoscopic staplers, and ultrasonic scalpels can effectively divide mesenteric vessels. For nonmobile sections of bowel, such as the duodenum and proximal jejunum, an intracorporeal sutured, stapled, or combination anastomosis is often performed. Distal jejunal and proximal ileal tumors are usually mobile enough to exteriorize through the abdominal wall for an extracorporeal resection and anastomosis.

Benign tumors

Benign tumors of the small intestine include adenomas, lipomas, hamartomas, and hemangiomas. Adenomas are the most common, and are classified as villous, tubular, or Brunner gland subtypes. Villous adenomas are primarily found in the duodenum, have a higher prevalence in familial adenomatous polyposis, and have the most malignant potential. Tubular adenomas are less likely to undergo malignant transformation, and Brunner gland adenomas are benign proliferations of the Brunner glands. Treatment of adenomas depends on pathology, location, and symptoms, and surgical options include local excision, pancreas-sparing duodenectomy, or even pancreaticoduodenectomy for ampullary tumors. Small bowel lipomas arise from the submucosal adipose tissue and are more common in the ileum. With growth, these tumors expand intraluminally and may become symptomatic. Lipomas that are asymptomatic and less than 2 cm can be followed, where symptomatic and large lipomas should be excised. Hamartomas arise from the smooth muscle of the muscularis mucosa and are associated with Peutz-Jeghers syndrome. Hamartomas can occur throughout the small bowel and can lead to obstruction, intussusception, or hemorrhage. Treatments range from polypectomies to bowel resections for complications of hamartomas. Hemangiomas usually present with occult gastrointestinal bleeding or iron deficiency anemia and are diagnosed by magnetic resonance imaging or capsule endoscopy. They are classified as cavernous, capillary, or mixed type, can be solitary or multiple, and are most commonly found in the jejunum. Surgical resection is preferred, but endoscopic sclerotherapy and angiographic embolization may be used for appropriately sized and located lesions.

Neuroendocrine tumors

Neuroendocrine tumors (NETs), formally known as carcinoid tumors, are the most common malignancies of the small intestine, with a higher prevalence in the ileum. NETs in the jejunum and ileum are usually serotonin-producing enterochromaffin-cell tumors, whereas a majority of tumors in the duodenum are gastrin-producing G-cell tumors.

Most NETs occur sporadically but may occur in multiple endocrine neoplasia type I or neurofibromatosis type 1 syndromes. These tumors can present as an intussusception or as an obstruction secondary to size or an intense desmoplastic reaction that results in adhesions, strictures, and contraction of the mesentery. Due to a delayed presentation in symptoms, metastatic disease to the lymph nodes is common, and an *en bloc* resection with a wide resection of the mesentery and extensive lymphadenectomy is recommended. The abdomen, including the liver, should be inspected for metastatic disease. Even in the setting of liver metastasis, the primary tumor should be excised to reduce tumor burden and associated complications of obstruction, bleeding, or perforation. If long-term treatment with somatostatin analogs is anticipated, a cholecystectomy should be considered at the time of initial surgery to prevent biliary symptoms from gallstone formation.

Adenocarcinoma

Adenocarcinoma is the second most common malignancy of the small bowel and is more commonly found in the duodenum, followed by the jejunum, and the ileum. However, in patients with Crohn disease, adenocarcinoma has a higher prevalence in the terminal ileum due to chronic inflammation. For early stage disease, segmental resection with negative margins, and a wide excision of the mesentery should be performed. However, adenocarcinoma of the first and second portions of the duodenum, or of the ampulla, requires a pancreaticoduodenectomy. Patients with locally advanced duodenal disease or metastatic disease not amenable to resection may benefit from surgical resection, bypass, or endoscopic stent placement.

Gastrointestinal stromal tumors

Gastrointestinal stromal tumors (GISTs) comprise 0.1% to 0.3% of small bowel tumors and originate from the interstitial cells of Cajal.⁷ The most common location is the stomach, but 30% are found within the small bowel with a higher prevalence in the jejunum.⁷ For localized disease, segmental resection should be performed. GISTs rarely metastasize to the lymph nodes; therefore, routine lymphadenectomy is not required. Locally advanced tumors should have an *en bloc* resection. The goals of resection are microscopically negative margins and an intact pseudocapsule. Therefore, great care is needed when handling GISTs laparoscopically. Tumor rupture has been associated with higher recurrence rates and decreased survival. Neoadjuvant therapy with imatinib can be given for unresectable GISTs, which may become resectable if responsive. Adjuvant therapy is recommended for intermediate- to high-risk GISTs. Laparoscopic resection has been associated with less narcotic use, quicker return of bowel function, and shorter length of stays compared to open surgeries.^{7,8} In addition, there is no difference

in oncologic outcomes, including recurrence rates, in patients with laparoscopic versus open resections.^{7,8}

Non-Hodgkin lymphoma

Non-Hodgkin lymphoma comprises a broad group of lymphomas including diffuse large B-cell, mantle cell, mucosa-associated lymphoid tissue (MALT) type, follicular, Burkitt, immunoproliferative, and T-cell lymphomas. Treatment depends on the type of lymphoma but is usually medical. Antibiotics against *Campylobacter jejuni* or *Helicobacter pylori* may be adequate for MALT lymphomas, and chemotherapy, radiation, and/or bone marrow transplantation are recommended for other forms of lymphoma. Resection can be considered for isolated tumors that are symptomatic, or complications of perforation and bleeding during chemotherapy.

MECKEL DIVERTICULUM

Meckel diverticulum results from incomplete closure of the omphalomesenteric or vitelline duct and is the most common congenital anomaly of the gastrointestinal tract with a prevalence of 2% in the general population. It is located in the distal ileum and can contain heterotopic pancreatic or gastric mucosa, which may lead to complications including bleeding, obstruction, and diverticulitis. Most Meckel diverticula become symptomatic in childhood and can be diagnosed with a technetium-99 m pertechnetate scan. Symptomatic Meckel diverticula should be resected. If inflammation from diverticulitis does not extend to the base of the diverticulum, and there is no concern for heterotopic mucosa, a laparoscopic stapled diverticulectomy can be performed. However, if the inflammation extends onto the small bowel, or there is concern for heterotopic tissue from complications such as bleeding, a segmental resection and anastomosis should be performed. Incidentally found Meckel diverticula are often resected in children, but a meta-analysis ascertained a higher than expected morbidity rate in asymptomatic patients, and that 758 resections are needed to prevent one Meckel-related death.⁹

CROHN DISEASE

Crohn disease is an inflammatory bowel disease with a prevalence of 50–100 per 100,000. This disease most commonly affects the terminal ileum and cecum in 55% of cases.¹⁰ Surgical treatment is required in approximately 70% of Crohn patients due to failed medical therapy, recurrent intestinal obstruction, malnutrition, and septic complications. Reoperative rates are as high as 90%, with 30% requiring multiple procedures.¹⁰ The laparoscopic approach to Crohn disease can be challenging, since the bowel is thickened, and

often associated with adhesions, fistula, and a foreshortened mesentery. In addition, patients are often malnourished and on chronic immunosuppression. The most common surgery performed is an ileocectomy for terminal ileal disease, but diagnostic laparoscopy, stricturoplasty, small bowel resection, repair of fistula, and a gastrojejunostomy for bypass of gastric or duodenal disease may be required. In all cases, it is paramount to adhere to bowel-preserving operative interventions, especially in the management of strictures. Laparoscopic intracorporeal stricturoplasties have been described but are difficult to perform. Alternatively, strictures can be marked laparoscopically with a silk or Vicryl suture, and then exteriorized through a small midline incision for a stricturoplasty or resection. A small number of retrospective studies have shown a reduced length of stay, reduced postoperative pain, improved social and sexual interaction, and decreased wound complications with a laparoscopic approach to Crohn disease.^{10,11} However, a Cochrane review of two randomized controlled trials found that laparoscopic surgery was as safe as open surgery, but there was no difference in the perioperative outcomes and long-term reoperation rates.¹⁰

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Laparoscopic surgery of the appendix

ERIC BALENT AND ROBERT B. LIM

INTRODUCTION

Surgeons have long been involved with technology and innovation in surgical technique in an effort to improve patient care. While laparoscopic surgery was invented in 1902 by Georg Kelling, MD, it took more than 77 years for the technique to find its place in the surgical arena. After the invention of the computer chip television camera, laparoscopic surgery became more feasible. In 1980, Kurt Semm, MD performed the first laparoscopic appendectomy, introducing a practical application for the laparoscopic technique.¹ While now viewed as a standard practice, the laparoscopic appendectomy was not always so well accepted. When Semm introduced the technique, he met much resistance and his methods were regarded as dangerous. Semm's technique was used by Erich Muhe, MD to perform the first laparoscopic cholecystectomy in 1985. Advances in insufflation, surgical energy devices, and the biomechanics of instrumentation have set the stage for complex laparoscopic surgery. Using these advances, surgeons have also developed different techniques to optimize the laparoscopic approach. With the invention of single-incision laparoscopic surgery (SILS), natural orifice transluminal endoscopic surgery (NOTES), and robot-assisted laparoscopic surgery, there are even more techniques. However, as varied as the techniques for laparoscopic removal of the appendix are, the tenants of surgery remain the same. Surgeons should have expert knowledge of the anatomy and its variants. They need to ensure good visualization of the organ including its attachments and its blood supply. Finally they need to use good surgical skill to ensure adequate and complete removal of the organ, along with safe control of its vasculature.

EPIDEMIOLOGY

Approximately 11 in 10,000 people will develop acute appendicitis in their lifetime.² Buckius et al. found that the highest

incidence of appendicitis was found in patients between 10 and 19 years of age, and the diagnosis was more common in males. In 2011, 327,000 appendectomies were performed in the United States, accounting for 2.1% of all operating room procedures. Appendectomy was the third most common procedure performed by general surgeons.³

ANATOMY

The appendix originates from the cecum as a true diverticulum, with all layers of the bowel wall. It originates as a bud off the cecum and is shifted medially as the cecal growth rate is greater than that of the appendix. The appendix exists as the fusion of the three taenia coli from the cecum. The ligament of Treves is on the antimesenteric side of the terminal ileum near the cecum and is also known as the ileocecal fold (**Figure 86.1**). The appendix can vary in its orientation in any direction from anterior to retrocecal. The appendiceal artery classically branches off of the ileocolic artery and travels within the mesoappendix. The lymphatic drainage follows the same path.

INDICATIONS

Again, the most common indication for a laparoscopic appendectomy is acute appendicitis. The leading theory of pathophysiology is that luminal obstruction by fecalith or lymphoid hyperplasia results in bacterial overgrowth, increased luminal pressure, and venous ischemia. The classic history includes periumbilical pain that migrates to the right lower quadrant. Other signs and symptoms include nausea, emesis, anorexia, and low-grade fever. Typical laboratory findings include a leukocytosis with a left shift.

Multiple scoring systems have been described to calculate the likelihood of acute appendicitis without using

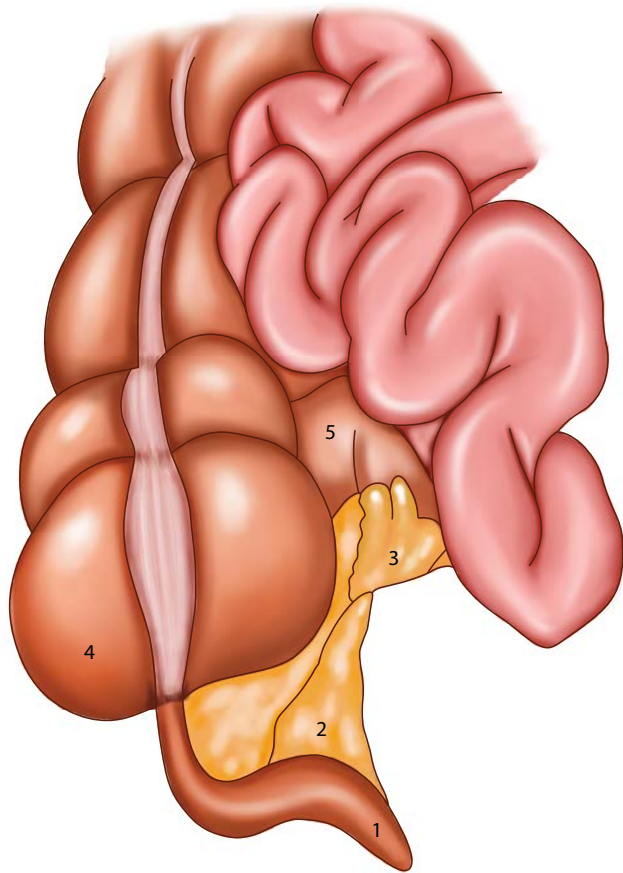


Figure 86.1 Appendiceal anatomy: (1) appendix, (2) mesoappendix, (3) ligament of Treves, (4) cecum, (5) terminal ileum.

radiographic analysis. The Alvarado score is one of the more commonly used. This scoring system is represented by the mnemonic “MANTRELS” which describes possible signs and symptoms. These consist of: migration of abdominal pain, anorexia, nausea, tenderness in the right iliac fossa, rebound tenderness, elevated temperature, leukocytosis, and shift on the complete blood count’s differential to neutrophilia. Right lower quadrant tenderness and leukocytosis add two points to the score, while the remaining factors contribute one point. A score of 5 to 6 indicates possible appendicitis, 7 to 8 indicates probable appendicitis, and a score of 9 to 10 indicates very probable appendicitis. However, Apisarnthanarak et al. found that the Alvarado score was only 60.4% specific for acute appendicitis with scores in the greater than 7 range.⁴

In clinical scenarios where the diagnosis of acute appendicitis is in question, imaging can be performed. Ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) have been described in the evaluation of the appendix. CT of the abdomen and pelvis is the most popular test with a 97.5% accuracy, 98.6% sensitivity, and 96.5% specificity in diagnosing acute appendicitis.⁴ In those patients who had a negative CT for appendicitis,

62% of them showed an alternative diagnosis.⁵ Concerning signs for appendicitis include a nonfilling appendix greater than 7 mm in diameter, periappendiceal fat stranding, and appendicolith. While CT with both oral and IV contrast is the traditional mode of imaging, Anderson et al. showed a similar sensitivity and specificity of CT with only IV contrast,⁶ while Rao et al. showed a 98% sensitivity and specificity with CT of the abdomen and pelvis with rectal contrast.

In adults, but more commonly in the pediatric population and in pregnant females, US and MRI of the abdomen and pelvis can be used. Ultrasound findings consistent with appendicitis include visualization of a tubular structure in the right lower quadrant that is noncompressible with a thickened wall.⁷ Gracey et al. have shown ultrasound to have a sensitivity of 93.8% and specificity of 91.3%, but Jaremko and Ang had shown a nondiagnostic rate of 56%–61%.^{8–10} MRI of the pelvis produced a 30% nonvisualization rate but a sensitivity of 91%.¹¹

An appendectomy can be performed for a few other suspected diagnoses. The application of interval appendectomy for patients who have previously suffered from appendicitis is an area of controversy. Advocates of the interval appendectomy state that removal of the appendix decreases risk of future episodes. Opponents of the procedure reply that the risk of developing recurrent appendicitis is approximately the same as the complication risk from the appendectomy. No clear consensus has been reached at this point.

Other indications for a laparoscopic appendectomy have been described. One prospective, albeit small, and several larger retrospective reviews have described the use of a laparoscopic appendectomy for the diagnosis of chronic appendicitis or chronic right lower quadrant pain when no other diagnosis can be found.^{12–14} The operation in this instance was safe and therapeutic in up to 87% of patients in both short-term and long-term (greater than 6 months) follow-up.¹⁴ Removal of the appendix has also been described to reduce clinical diagnostic difficulty in patients with intestinal malrotation and Crohn disease. In patients with Crohn disease who undergo an exploration for abdominal pain, the appendix may be removed to eliminate it as an etiology for future presentations of abdominal pain. However, the cecum must be inspected prior to removing the appendix. If the cecum shows active inflammation, then removing the appendix may be complicated by a leak due to the poor healing of Crohn disease patients; thus, it is not recommended.

SURGICAL TECHNIQUES

After the decision is made to perform a laparoscopic appendectomy, the following preparation is recommended. Patients should be started on therapeutic antibiotics for the appendicitis. Foley catheter placement for decompression of the bladder to avoid injury during trocar placement is also suggested. The catheter can be removed at the end of the case. The patient is placed on the operating room table in the supine position typically with the left arm tucked. This

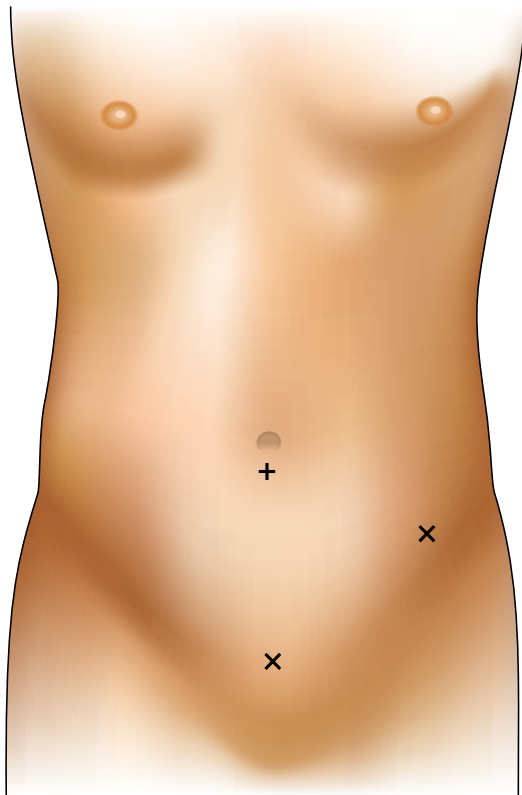


Figure 86.2 Trocar placement for laparoscopic appendectomy: +, the periumbilical trocar; x, the suprapubic and left lower quadrant trocars.

allows the surgeon to have a greater range of motion and allows more room for the assistant, as both may be on the patient's left. The entire abdomen is prepped from the nipple line to the superior thighs. A belt should be placed to secure the patient to the operating table.

The traditional port position described for the laparoscopic appendectomy includes a periumbilical site, a left lower quadrant site, and a suprapubic site. This allows triangulation of instruments to approach the appendix in the right lower quadrant (**Figure 86.2**). However, these port sites may be altered depending on the patient's anatomy or surgical preference. If a CT of the abdomen and pelvis has been performed, it is useful to correlate appendiceal location and planned trocar sites. If a laparoscopic stapler is to be used in order to divide the appendix and mesoappendix, a 12 mm trocar will be required. The larger port will also allow for removal of the specimen from the body. The other two ports are typically 5 mm ports to minimize surgical trauma, pain, and incisional hernia occurrence. In pregnant patients, the appendix typically migrates toward the right upper quadrant, and the port placement must be adjusted to accommodate these changes. Also, it is recommended that the initial port is placed using the open Hasson technique due to decreased intra-abdominal space and avoidance of a blind trocar or Veress needle placement. The abdomen is

insufflated to 12–15 mm Hg in order to visualize its contents. Greater pressures may result in compression of the inferior vena cava and increase the risk of air embolism.

Once a pneumoperitoneum is established and the appropriate ports are placed, the first step of the operation is to do an exploration. If the appendix is normal, then the exploration should include inspection of the large bowel for colitis, the stomach for a perforating ulcer, the gallbladder for cholecystitis, the liver for lesions that may cause pain, the small bowel for a Meckel diverticulum, and the mesentery for adenopathy. In the case of females, the ovaries and uterus should be examined for their pathology. A preoperative CT scan may not have any evidence of these diseases, but abnormalities may be seen intraoperatively. A normal appendix mandates this thorough investigation. Additionally, the possible intra-abdominal pathologies are not limited to those previously described above. Finally, an inspection should be done of the abdominal wall for bleeding and in the areas below the ports to determine if any injuries occurred because of the port placement.

After the exploration has been done, the appendectomy is done with the patient in a Trendelenburg position and with the right side of his or her abdomen elevated. The appendix should be grasped and retracted both anteriorly and toward the pelvis. Because the appendix is an intra-abdominal organ, and because it is usually removed when it is infected, it can adhere to other organs in the abdomen and pelvis or be in a retrocecal position. To help find its base, one can trace the taenia of the colon down to the cecum. Alternatively, one could trace the terminal ileum to identify the ligament of Treves. If an infected appendix is present, the ligament of Treves is likely to adhere to the mesoappendix (**Figure 86.3**). The infected appendix may have to be dissected away from the surrounding organs or the abdominal wall. This can usually be done bluntly but may require sharp dissection also.

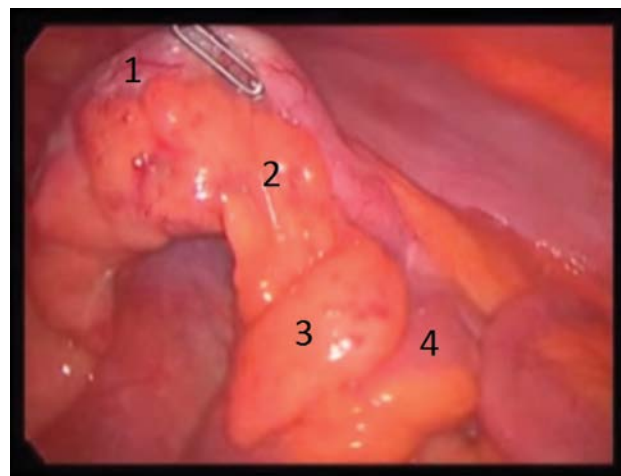


Figure 86.3 Intraoperative anatomy: (1) appendix, (2) mesoappendix, (3) ligament of Treves, (4) terminal ileum. (Photo credit: Shahram Nazari, MD.)

There are two basic ways to remove the appendix. The first technique is to divide the mesoappendix first. Different methods include the use of Endoclips, endostapler, monopolar energy, ultrasonic devices like the Harmonic scalpel (Ethicon Endo-Surgery, Cincinnati, Ohio), and bipolar electrocautery devices like the Ligasure (Covidien, Mansfield, Massachusetts) to dissect the mesoappendix and control the appendiceal artery. Lee et al. found no significant difference between hospital stay, wound infection, abscess, hemorrhage, or conversion to open procedure between Endoclip, Harmonic scalpel, or monopolar energy. However, the Harmonic scalpel was found to have a decreased average operative time but at an increased cost.¹⁵

After the mesoappendix has been dissected and the appendiceal artery divided, the appendix must be removed at its base. The original technique used to ligate the base of the appendix was performed with the use of Endoloop suture. By placing one to two Endoloops on the cecal side of the appendiceal base and an additional loop on the appendiceal side, the appendix could be ligated to prevent spillage of fecal contents when it is divided. The advantage of the Endoloop is that it only requires a 5 mm port, instead of the 12 mm port. However, there is a theoretical risk of spillage.¹²

Alternatively, an endostapler can be used. Since the endostapler ligates the appendix with multiple rows of staples and divides precisely between the staples, there is less theoretical risk of spillage. In either method, the appendiceal stump should be inspected for evidence of leakage. If some is present, then the stump can be inverted into the cecum and sutured into that position using a silk figure-of-eight stitch. Swank et al. reported similar complication rates between patients who received the two different forms of appendiceal ligation, but the endoscopic stapler group had a significantly higher cost. The endostapler has been recommended for use in appendices that have a broad base or perforation near the base of the appendix.¹⁶

The second basic technique of removing the appendix is to divide the base of the appendix first. Here a window is made in the mesentery at the base of the appendix. This should be done with a blunt instrument, as sharp ones may go through the mesentery too easily and injure the cecum that may be lurking behind the mesoappendix. To that end, gentle retraction toward the surgeon should be placed on the appendix to make penetrating the mesoappendix easier. Also one should visualize the other side of the mesoappendix before trying to make a window in it. Once a window is made in the mesoappendix, the endostapler is fired across the base while the appendix is retracted inferiorly and anteriorly. Next, the mesoappendix is divided using an endostapler with a vascular load, or it can be controlled using one of the techniques described earlier. Again the base of the appendix should be examined for leakage.

After the appendix has been transected free from the cecum, it is removed from the abdomen. The use of an endoscopic bag for retrieval of the appendix or removal of the trocar while the appendix is contained within it has been described to avoid infecting the wound that the appendix

is brought through. The appendix is then inspected to ensure an appendicolith is found if one was visualized preoperatively on imaging. A retained appendicolith places the patient at significant risk for abscess formation. After removal, the staple lines are inspected for hemostasis. The abdomen is allowed to decompress, and trocars are removed under direct visualization. Incisions through the fascia that are 1 cm or greater in length should be closed primarily. This can be accomplished by open repair or use of a percutaneous laparoscopically assisted closure device. Fascial incisions that are 1 cm or greater in length are at significant risk for incisional hernia.¹⁷

Single-incision laparoscopic appendectomy has been studied in order to determine if there is an advantage in recovery time, postoperative pain, and outcomes. A variety of ports and laparoscopes have been used and described in order to facilitate the shortest operative time and best visualization of the necessary anatomy. With the single-incision port, a laparoscope and two to three additional instruments can be utilized through a single 2–3 cm incision. The rate of complications has been described as similar between conventional laparoscopic surgery and single-incision laparoscopic surgery; however, Liang et al. reported a significantly higher wound infection rate.¹⁸ Also, due to its more recent development, there is a sharper learning curve with single-incision laparoscopic surgery with an increased operative time.

COMPLICATED APPENDICITIS

Complicated appendicitis is defined as appendicitis that is associated with a gangrenous or perforated appendix, or the appendicitis is associated with an abscess. In this instance, a laparoscopic appendectomy can be safely performed with a shorter length of stay and lower incidence of a superficial surgical site infection according to a review of the National Surgical Quality Improvement Program database of almost 2,800 patients with complicated appendicitis. However, it appears that the laparoscopic approach is also associated with a higher rate of deep surgical site infections.¹⁹ There is no conclusive data that recommend the use of a drain routinely for complicated appendicitis to decrease deep space infections.^{20,21} Also, the optimal duration of antibiotic treatment for perforated appendicitis is unknown with the majority of patients receiving treatment for 5–7 days.

POSTOPERATIVE CARE

After successful appendectomy for nonperforated appendicitis, the majority of patients can be discharged within a 24- to 48-hour period. Pain control typically consists of an oral narcotic with an acetaminophen component. Patients are started on a clear liquid diet and advanced to a regular diet if they have tolerated the liquids. Antibiotics are discontinued within 24 hours. There is also a concerted move to discharge the patients from the postanesthesia recovery unit using a pathway, but

this is more prevalent in the pediatric surgery literature. For cases of uncomplicated appendicitis, many patients can be discharged to home within a few hours after surgery without an increase in complications or readmission rates.²²

DISCLAIMER

The views expressed in this manuscript are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.

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Laparoscopic surgery for benign disease of the colon: Diverticulitis

ALI LINSK BUTASH AND KETAN SHETH

BACKGROUND

Laparoscopic colon resection may soon supplant open colectomy as the gold standard operation for both benign and malignant colonic pathology. When performed by experienced surgeons, laparoscopic colon resection has been shown to be safe and produces equivalent or better outcomes when compared with open colectomy. A Cochrane review meta-analysis of 25 randomized controlled trials concluded that despite having longer operative times, patients who undergo laparoscopic colon resection have less intraoperative blood loss, better postoperative pain control, shorter duration of postoperative ileus, improved pulmonary function, decreased surgical morbidity, and shorter postoperative hospital stays when compared to patients who undergo open colon resection. There was no difference in overall morbidity and mortality between the open and laparoscopic groups.¹ This chapter focuses on the utility of laparoscopic surgery for diverticulitis.

The overall prevalence of diverticular disease and the rates of hospital admission for diverticulitis have been increasing in recent years. There is a growing body of literature that has looked at the process of patient selection for elective sigmoid colectomy in cases of recurrent diverticulitis. The review of this literature is beyond the scope of this chapter but can be summarized by saying that the decision to recommend elective colon resection should be individualized, taking into account the number of prior attacks, the impact of recurrent disease on the patient's lifestyle, the patient's operative risk, and the patient's medical comorbidities.² The indications do not change for minimally invasive approaches. Careful patient selection and optimal timing of operation are paramount for successful laparoscopic resection for diverticulitis. Both right-sided

and left-sided diverticular disease are amenable to a minimally invasive approach.

In recent years, laparoscopic sigmoid resection specifically for diverticulitis has been looked at in detail in both randomized controlled trials and large clinical and administrative database reviews. We summarize the major findings of these studies and highlight the clinical practice guidelines that have subsequently been developed for both elective and urgent surgical approaches. It is important to note that patient selection and surgeon experience are essential when determining the appropriateness of a minimally invasive approach to colon resection for diverticular disease.

ROLE OF LAPAROSCOPY IN ELECTIVE SIGMOID RESECTION

Recurrent diverticulitis

A query of the National Inpatient Sample (NIS) database compared outcomes of elective laparoscopic and open surgical approaches for diverticulitis. Over 120,000 cases from 2002 to 2007 were reviewed, of which 88.3% were done open and 11.7% were done laparoscopically. The laparoscopic group had a 0.63% intraoperative complication rate, and the open group had a 1.15% intraoperative complication rate, which was statistically significant ($p < 0.01$). Additionally, ureteral injuries were comparable in open and laparoscopic approaches, 0.17% and 0.12%, respectively. Postoperative complications such as anastomotic leak, abscess, ileus, wound infection, bowel obstruction, urinary tract infection, respiratory complications, and venous thromboembolic disease were all noted to be higher in the open group when compared to

the laparoscopic group. Length of hospital stay and total hospital charges were lower in the laparoscopic group. Mortality was also four times lower in the laparoscopic group when compared to the open group (0.15% versus 0.54%, $p < 0.01$).³

The Sigma trial was a prospective, multicenter, double-blind, randomized controlled trial conducted from 2002 to 2006 across five centers. For this trial, 104 patients were matched and randomized to laparoscopic or open sigmoid resection arms. The conversion rate from laparoscopic to open was 19.2% in this population. Minor complication rates were similar in both groups. Operative time was longer, pain control was better, pain medication requirement was less, and hospital stay was shorter in the laparoscopic group. Quality of life scores were higher as rated by patients in the laparoscopic group. The most powerful finding in this trial is that major complications were much higher in the open group at 25% versus 9.6% in the laparoscopic group. The major complications in this study included reoperation within 30 days from surgery, anastomotic leakage, intra-abdominal abscess, and severe postoperative bleeding with requirement for blood transfusion.⁴ The long-term outcomes demonstrated no significant differences in late clinical outcomes during the 30-day to 6-month follow-up period but highlighted the overall decreased complication rate over the total follow-up period of 0–6 months and higher quality of life rating at the 6-week mark seen in the laparoscopic group.⁵

Another randomized trial from Switzerland included 113 patients at a single center from 2005 to 2009. In this population, 76 hours (range 31–163) was the median time to first bowel movement in the laparoscopic group with 105 hours (53–175) being the median time in the open group ($p < 0.0001$). The intraoperative time was again significantly longer in the laparoscopic group, median of 165 minutes compared to a median of 110 minutes in the open group ($p < 0.0001$). Pain scores were relatively similar between the groups in this population. Length of stay was longer in the open group and who may have otherwise done well with conservative 8.5% of laparoscopic cases were converted to open. There were no mortalities and no anastomotic leaks in this group.⁶ The long-term follow-up of these patients showed comparable Gastrointestinal Quality of Life Index scores and diverticulitis recurrence rates in the laparoscopic and open groups. The hernia rate in the laparoscopic group was one-third that of the open group. The median follow-up was 30 months at the time of publication.⁷

In 2014, Feingold et al. published a set of diverticulitis practice parameters in the colorectal literature that recommended a laparoscopic over an open approach for elective colectomy when the appropriate expertise is available. This was a strong recommendation based on high-quality evidence (level 1A) in the studies previously outlined.²

Fistulous disease

Studies looking at the role of minimally invasive surgery in fistulous diverticular disease are mostly small case

series with heterogeneous results. Patients with recurrent, chronically inflamed, or complicated diverticulitis often have some component of fistula formation. Performing the procedure entirely laparoscopically may be challenging, but it does not rule out the approach. Utilization of a hybrid approach that involves a combination of laparoscopic and open technique may still prove beneficial to the patient. The use of a hand port may also help preserve a laparoscopic approach. In a review of the evidence, Bissolati et al.⁸ looked at four series with 18, 16, 31, and 14 patients, respectively, with conversion rates ranging from 5.5% to 36% and operative times ranging from 150 minutes to 237 minutes. One study by Bartus et al.⁹ compared laparoscopic resections for fistulous disease in 36 patients with a group of 146 patients who underwent laparoscopic resections for uncomplicated disease and not surprisingly found that complicated fistulous disease required longer operative times and more frequent conversion to open. Interestingly, length of stay, leak rate, and other complications were not seen to be different between the groups. At present, there is lack of consensus data regarding minimally invasive surgery in fistulous disease, but it is likely reasonable to consider starting with a laparoscopic approach and progressing based on experience and level of skill prior to conversion to an open technique. Often the parameters that made it difficult laparoscopically will also make for a challenging open case.

ROLE OF LAPAROSCOPY IN ACUTE PERFORATED SIGMOID DIVERTICULITIS: LAPAROSCOPIC PERITONEAL LAVAGE

Historically, perforated diverticulitis with purulent or fecal peritonitis (Hinchey III or IV) has been treated with open surgery involving colon resection and stoma formation via a Hartmann procedure. Laparoscopic peritoneal lavage has evolved as a potential alternative to a Hartmann procedure in patients with purulent peritonitis, with the suggestion that it may decrease the need for stoma formation and improve patient outcomes. This is still controversial, and many surgeons believe that laparoscopic lavage is not a safe alternative to resection and stoma formation in these patients. In addition, the practice of interventional radiology has also matured, and many cases of complicated diverticulitis are managed with percutaneous drainage and close surgical input and management. Approaches are often dictated by the individual patient's overall condition and hemodynamic status. Nevertheless, laparoscopic lavage should be in the armamentarium of the modern-day minimally invasive surgeon.

The majority of the literature published on laparoscopic lavage through 2014 had been in small case series and often limited by study design. For example, multiple studies were retrospective and included Hinchey I or II stage disease and patients with fewer comorbidities who may have otherwise done well with conservative management. As of 2014, Feingold et al.² called for a higher quality of evidence in

order to comment on the safety and utility of lavage, noting that until that level of evidence is obtained, the current recommendation is to continue with resection and diversion in patients with purulent and feculent peritonitis.

A prospective, multi-institutional study with 100 patients attempted laparoscopic lavage in all cases with only eight patients requiring a conversion to an open Hartmann procedure after finding fecal peritonitis at the time of surgery. The remaining 92 patients underwent laparoscopic lavage. Two of these patients required postoperative drainage of pelvic abscesses. Two patients had recurrent diverticulitis during the median 36-month follow-up. The 92 patients who had laparoscopic lavage had a morbidity rate of 4% and a mortality rate of 3%. This study demonstrated the overall safety of laparoscopic lavage and served as a basis for designing randomized controlled trials that looked more closely at lavage in this setting. To date, all of the randomized controlled trials have been conducted in Europe and will be outlined in the following text.¹⁰

A Scandinavian multicenter randomized controlled trial (DILALA—diverticulitis laparoscopic lavage), looking at laparoscopic lavage recently published results from the first 12 weeks postoperatively. This trial included 39 patients randomized to laparoscopic lavage compared with 36 patients randomized to Hartmann procedure after initial diagnostic laparoscopy in all patients. All patients had findings of purulent peritonitis at the time of diagnostic laparoscopy. Short-term morbidity and mortality rates did not differ, but the laparoscopic lavage group had shorter operative times and shorter length of stays.¹¹

In another multicenter randomized controlled trial recently published out of Sweden and Norway (SCANDIV), the outcomes of patients who underwent laparoscopic lavage were compared to those who underwent colon resection in the setting of perforated diverticulitis. Included were 199 patients from 21 centers from 2010 to 2014. In this trial, 101 patients were randomized to laparoscopic lavage and 98 were randomized to colon resection. The primary outcome was the occurrence of severe postoperative complications within 90 days of surgery: 30.7% of patients in the lavage group had severe outcomes versus 26% of patients in the resection group, which was not statistically significant. The mortality data were also similar between groups: 13.9% in the lavage group and 11.5% in the resection group. Further, 20.3% of patients in the lavage group required reoperation, whereas only 5.7% of patients in the resection group

needed reoperation within 90 days. The length of operating time was less in the laparoscopic lavage group, but the quality of life and length of stay data were comparable between the two groups. Overall, this trial provides strong evidence against a role for laparoscopic lavage. The lavage group had a high reoperation rate without a reduction in severe postoperative complications or mortality in comparison to the resection group.¹²

Another large multicenter randomized study in Belgium, Italy, and the Netherlands (the Ladies trial) had to be terminated early by the data and safety monitoring board after a high rate of morbidity and mortality was seen in the lavage group. Although of note, the morbidity and mortality rates were comparable to those seen in the sigmoid resection group during that same time period. There is another arm of that trial that is still underway comparing the Hartmann procedure to primary anastomosis.¹³

SUMMARY

Minimally invasive approaches to diverticular disease continue to gain traction. Importantly, not all cases are appropriate for a laparoscopic approach, and an open technique should be utilized when laparoscopy is contraindicated. Careful patient selection and ongoing advancement of technical skills will optimize outcomes after minimally invasive surgery for diverticular disease.

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Laparoscopic resection for carcinoma of the colon

JARED WONG AND JAMES FLESHMAN

INTRODUCTION

The use of laparoscopy for colon surgery has steadily grown since 1991, with adoption rates up to 40% in 2010.^{1,2} Multiple prospective randomized trials and meta-analyses confirm laparoscopic colon surgery to be oncologically equivalent to open approaches.^{3,4} Laparoscopic treatment of colon cancer requires the use of advanced minimally invasive techniques. The surgeon must work in multiple quadrants of the abdomen, follow embryologic dissection planes, protect small structures such as the ureters, and operate on and around critical blood vessels.

PREOPERATIVE CONSIDERATIONS

Factors that may be relative contraindications to laparoscopic surgery include the presence of intra-abdominal abscess or fistulas, advanced or large tumor, bowel obstruction, marginal pulmonary status, obesity, ASA score greater than three, multiple prior abdominal operations, and hemodynamic instability.

PATIENT POSITIONING, OPERATIVE BED, AND MONITOR PLACEMENT

The patient is placed in modified lithotomy position on a fixation pad (deflatable beanbag or memory foam) to provide the surgeon additional angles from which to operate. The legs are placed in padded calf-high stirrups in a slightly flexed position to minimize the chance of peroneal nerve injury. The thighs should run parallel with the hips to allow for maximal working motion of the instruments

above the legs. Arms should be padded at the elbows and wrists and tucked bilaterally, to allow for maximal working space.

The ideal number of monitors is three, with two opposite the operating surgeon at shoulder and knee level and one across from the assistant, moved to the point of instrumentation alignment at each stage of the operation. The working monitor is positioned adjacent to the left hip when performing a sigmoid resection or low anterior resection, at the level of the left shoulder for mobilization of the splenic flexure, and lateral to the right hip and right shoulder when performing a right colectomy ([Figure 88.1a and b](#)).

An open cut-down technique is recommended for the initial umbilical port placement. Following insufflation, a brief survey of abdominal contents is performed to determine the presence of adhesions or metastatic disease. Each subsequent port is placed under direct visualization. When using a hand port, the hand access incision is made first, and the remaining ports are placed under hand guidance. When extracting the specimen, we advocate the use of a wound protector as it is helpful for stretching the abdominal wall opening, providing full circumferential retraction of the wound edges, and minimizing the risk of seeding cancer at the extraction site. The extraction site for a left colectomy is at the pubis symphysis and for a right colectomy at the umbilicus.

GENERAL CONSIDERATIONS/TECHNIQUES

Laparoscopic surgery should never compromise the principles of open surgical technique. Potential reasons for conversion to an open procedure include, but are not limited

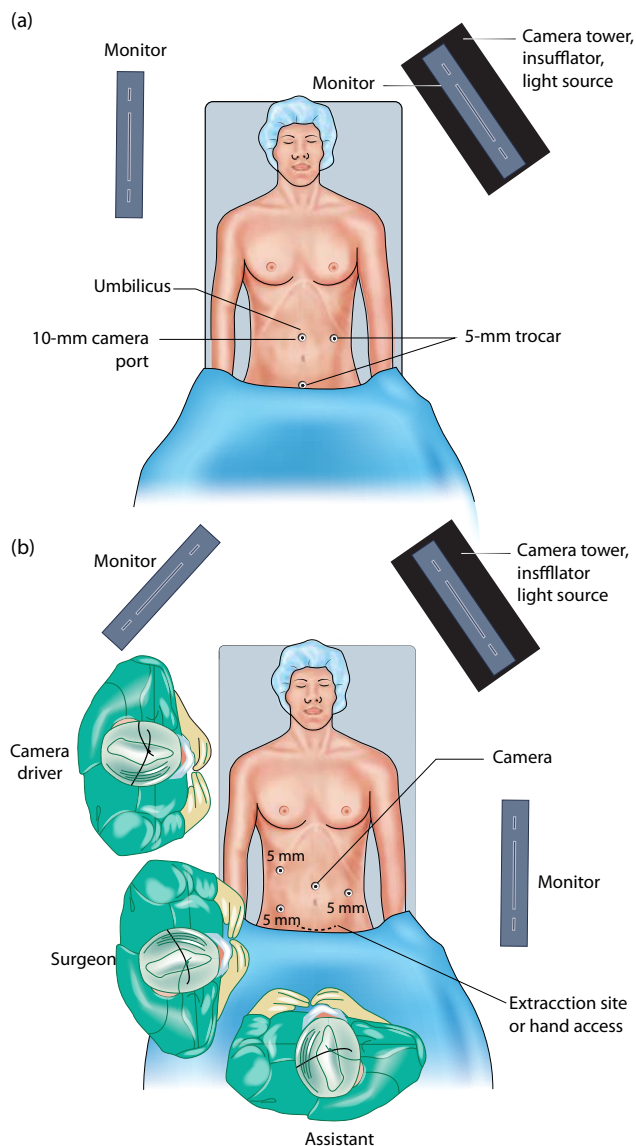


Figure 88.1 Laparoscopic treatment of colon cancer: (a) Patient position, monitor setup, and trocar pattern for right colectomy. (b) Patient position, monitor setup, surgeon position, and trocar pattern for left colectomy.

to, the following: inability to visualize important structures (ureters), inability to perform an adequate oncologic resection when needed (high ligation of vessels), malignant invasion requiring wide resection, dense adhesions requiring intense sharp dissection, uncontrolled bleeding, or peritoneal soiling secondary to an uncontrolled enterotomy.

RIGHT COLECTOMY

Preoperative planning

The operating surgeon and camera operator stand on the left side of the patient, while the assistant stands in between

the legs. Monitors are placed at the right shoulder, right knee, and left shoulder. The camera port is placed in the lower rim of the umbilicus. Two additional 5 mm ports are placed under direct visualization; a midline suprapubic port and a mid-left quadrant port (lateral to the rectus muscles) ([Figure 88.1b](#)).

Procedure details

It is the practice of this author to perform a posterior, medial-to-lateral approach to a right colectomy. The patient is initially positioned in Trendelenburg and left side down. The cecum is lifted anteriorly, flipping the small intestine gently out of the pelvis up to the transverse colon, thus exposing the right iliac vessels at the pelvic brim. An incision is made along the peritoneum in the avascular plane anterior to the right iliac artery and inferior to the ileocecal mesentery. This provides entry into the avascular plane between the retroperitoneum and right colon mesentery and exposes the right ureter as it crosses the iliac vessels ([Figure 88.2](#)). The plane between the right colonic mesentery and retroperitoneum is developed by dissecting bluntly in a lateral direction, to the sidewall attachments of the colon, and superiorly, up over the right kidney to the inferior edge of the liver. Medially, the transverse colon and mesocolon are gently separated off the duodenal sweep and the superficial portion of the anterior head of the pancreas, with special care to avoid tearing of pancreaticoduodenal and middle colic veins. The entire right mesocolon should thus be lifted free from the retroperitoneum, and the duodenum, right kidney and ureter, gonadal vessels, and inferior vena cava are undamaged and clearly visible from the pelvic brim to the upper pole of the right kidney from the midline to the right sidewall of the abdomen.



Figure 88.2 The ileocolic vessel is placed under tension, and the mesenteric windows proximal and distal along the SMA are identified, incised, and opened to show the base of the ileocolic artery.

Hepatic flexure mobilization

To mobilize the hepatic flexure, the patient is transitioned to reverse Trendelenburg position. The transverse colon is retracted inferiorly, placing the gastrocolic ligament under slight tension. The lesser omental sac is entered through the gastrocolic omentum at the middle of the transverse colon, and the omentum is divided outside the gastroepiploic arcade using a vessel-sealing device. Dissection is continued laterally, avoiding ligation of the gastroduodenal artery and damage to the first and second duodenum, dividing the gastrocolic and, subsequently, the hepatocolic ligaments. As the lateral attachments of the ascending colon are finally divided along the white line of Toldt, the ascending colon falls medially.

High ligation of ileocolic vessels and mesentery

The small intestine is then flipped back into the pelvis to allow visualization of the medial surface of the right colon and its mesentery. The ileocolic vessels are grasped toward the base of the cecum and retracted toward the iliac fossa. The vascular pedicle is exposed nicely between two windows of thinned mesentery and can be sealed at the superior mesenteric artery. Continuing cephalad from the divided ileocolic vessels, the ascending and transverse mesocolon are divided with an energy device. The specimen is secured in its anatomic position in preparation for extraction.

The umbilical port site is enlarged to a 5 cm vertical incision. The specimen is extracted through a wound protector with enough length to perform the anastomosis. A stapled side-to-side, functional end-to-end anastomosis is constructed.⁵ Care is taken to avoid twisting the bowel when constructing the anastomosis by closing the mesenteric defect, and the transverse staple line is oversewn. The fascia of the extraction site is closed with a running heavy absorbable suture (**Figure 88.3**).

LEFT, SIGMOID COLECTOMY, LOW ANTERIOR RESECTION

Preoperative considerations

The surgeon and camera operator stand on the right side of the patient. It may be preferable for the operator to stand in between the patient's legs when mobilizing the splenic flexure. The assistant stands on the left side of the patient. Monitors should be placed above the patient's left shoulder, lateral to the patient's left hip, and an additional monitor should be on the right side for the assistant.

Procedure detail

A medial-to-lateral approach allows for initial vessel control, allows for clear visualization of the ureter early in the

dissection, and prevents redundant left and sigmoid colon from obscuring the camera view as it remains attached to the lateral sidewall. Complete mobilization of the splenic flexure is routinely performed to provide adequate length for a tension-free and well-vascularized low pelvic anastomosis.

The camera port is placed slightly above the umbilicus in the midline. A 10–12 mm port is placed in the suprapubic region along the midline. Alternatively, a hand port can be placed at this location through a Pfannenstiel incision. A 5 mm port is placed two fingerbreadths below the rib cage in the right anterior axillary line and two fingerbreadths above the right anterior superior iliac spine on a line to the umbilicus. A third 5 mm port is placed in the left anterior axillary line at the level of the umbilicus (**Figure 88.1b**).

The patient is placed in steep Trendelenburg with left side up. The small bowel is gently lifted out of the pelvis. Using an atraumatic grasper or the pinched finger and thumb (in the hand assist), the medial aspect of the mesosigmoid at the sacral promontory is gently retracted anteriorly, bringing the inferior mesenteric vessels into view. The plane of dissection begins by scoring the peritoneum at the base of the rectosigmoid mesentery, posterior to the superior hemorrhoidal vessels, and anterior to the left iliac vessels and left ureter. Blunt dissection lifts the inferior mesenteric and superior hemorrhoidal vessels away from the presacral autonomic nerves, ureter, and iliac vessels. The left ureter should be identified crossing the anterior aspect of the proximal left common iliac vessels (**Figure 88.4**). The areolar tissue plane is developed in the upper pelvis before the mesosigmoid is divided with an energy device up to the inferior mesenteric artery (IMA). The IMA is then isolated and sealed near its origin at the aorta (**Figure 88.5**). The plane of dissection continues cranially over the retroperitoneal structures until the inferior mesenteric vein (IMV) is encountered and sealed at the inferior border of the pancreas and lateral to the ligament of Treitz. Blunt dissection continues laterally until the lesser omental sac is entered over the tail of the pancreas and the posterior attachments of the splenic flexure are incised to the left abdominal sidewall. The descending colon is fully mobilized by retracting the descending colon anteromedially and dividing the lateral attachments along the white line of Toldt.

Splenic flexure mobilization

Splenic flexure mobilization is accomplished in reverse Trendelenburg position and left side up. The surgeon may find it easier to perform this dissection while standing between the patient's legs. Initially, the descending colon is displaced anteromedially, and the prior dissection point along the lateral sidewall is continued superiorly, carried across the tip of the spleen. The greater omentum is retracted cephalad and released from the distal transverse colon all the way across the transverse colon. The left colon is retracted medially, and the freed mesentery is lifted off Gerota fascia. Any remaining

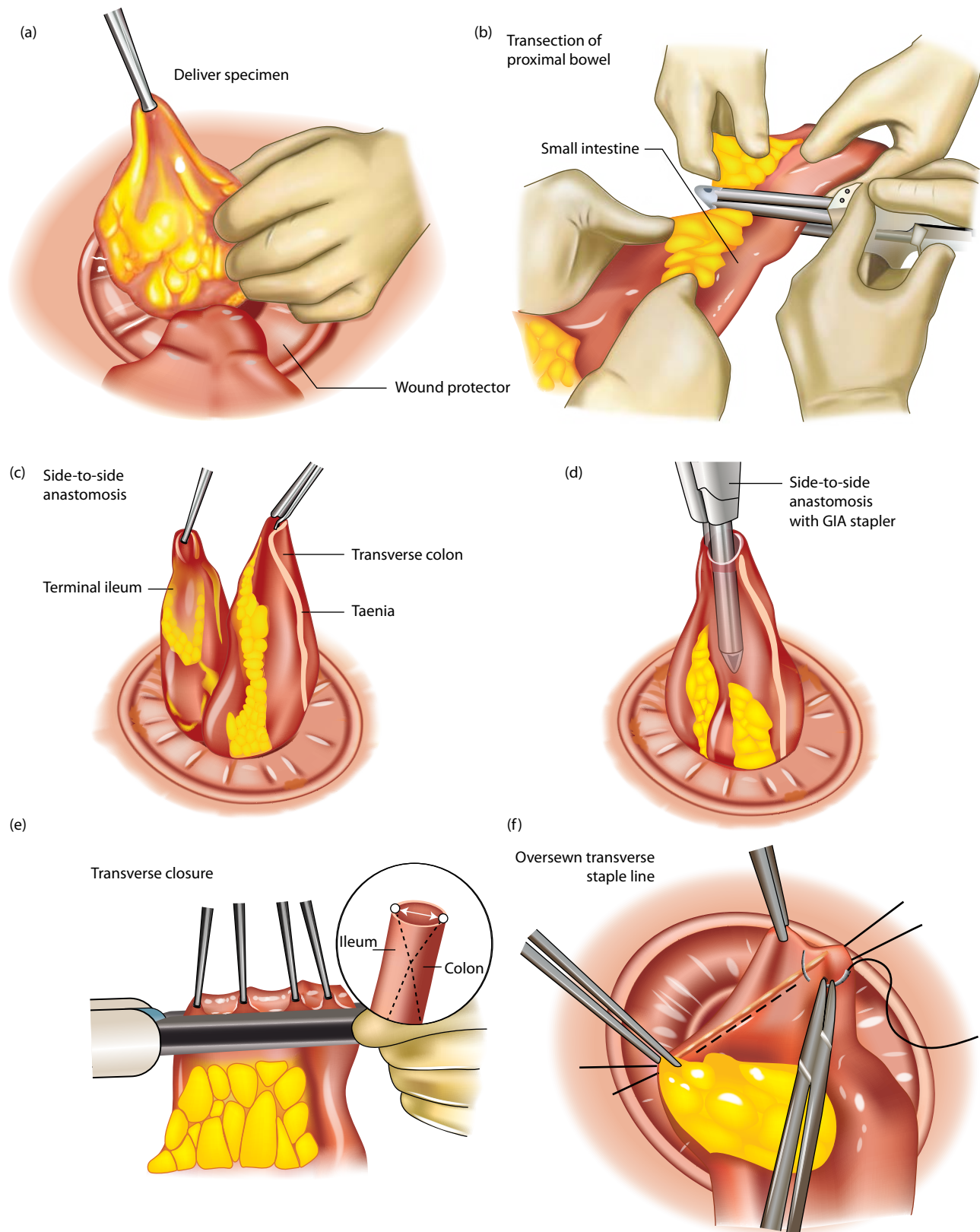


Figure 88.3 Right colectomy: (a) The colon and terminal ileum are extracted through a wound protector, (b) divided proximally and distally, and (c) aligned with antemesenteric surfaces adjacent without twist. (d) The GIA stapler is placed through excised corners of the staple lines and lined up to create a side-to-side opening. (e) The transverse opening is closed with a second firing of the stapler. (f) The transverse staple line is oversewn.

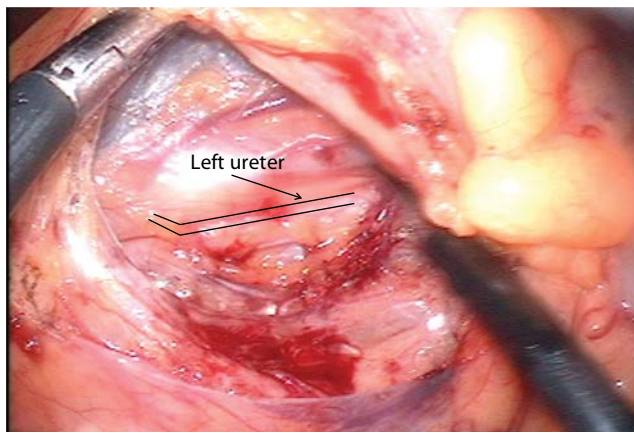


Figure 88.4 The incision is made along the base of the triangle to expose the sacral promontory and areolar tissue plane with blunt downward dissection. The left ureter is seen in the dissection plane.

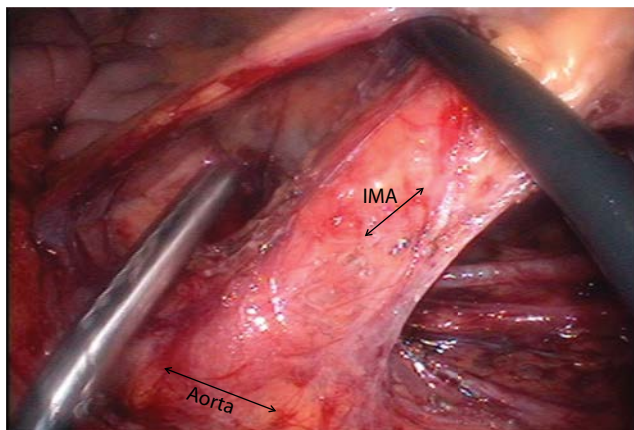


Figure 88.5 The IMA is cleared at the aorta, after a window is made proximal to the IMA along the base of the left colic mesentery.

retroperitoneal attachments are divided. The proximal site of planned resection is pulled into the pelvis to ensure that there is adequate mobility to create a tension-free anastomosis.

Rectal dissection

The patient is returned to steep Trendelenburg position. The mesorectum is retracted superiorly and anteriorly so that the rectum is drawn up out of the pelvis under slight tension. Careful attention is required to perform this dissection anterior to the ureters, hypogastric nerves, and internal iliac arteries. Dissection in the avascular plane between the mesorectum and the presacral fascia proceeds caudally. The peritoneal attachments are divided on each side of the pelvis over the dissected areolar tissue plane. The ureters course

over the iliac vessels and move laterally along the pelvic brim before they swing medially to enter the posterior bladder. An anterior incision is made 1–2 mm anterior to the deepest extent of the pouch of Douglas. Denonvillier fascia is swept anteriorly, separating the seminal vesicles from the mesorectum in males and the posterior vaginal wall from the anterior wall of the rectum in females. The mesorectal dissection and mobilization of the rectum should extend at least 4–6 cm below the tumor and onto normal soft rectum.

Transection of the rectum is performed with an articulating endoscopic stapler with 3.5 mm stapler height. More than one firing of the stapler is commonly needed to fully transect the rectum. It is important in oncologic resections to ensure that the mesorectum is divided perpendicular to the rectum to avoid coning in on the mesorectum and leaving involved lymphatic material behind in the pelvis. The specimen is extracted through a protected 5 cm transverse suprapubic or a muscle splitting incision created in the left lower quadrant. When using the hand-assist technique, the hand access port is used as the extraction site.

A pursestring is placed around the anvil of a circular stapler in the selected anastomotic site of the proximal colon. The colon is returned into the abdominal cavity, and the extraction wound is closed. Alternatively, the wound protector is twisted and clamped to reestablish pneumoperitoneum. In hand-assisted cases, the anastomosis is accomplished through the open suprapubic incision.

A circular stapler is passed to the staple line in the rectal stump and opened. The post piercing the middle of the staple line is then connected to the anvil in the proximal colon without rotation and closed under direct visualization, taking care to avoid incorporating the vagina. The stapler is fired and gently withdrawn. The distal and proximal “donuts” are inspected for completeness. An “air-test” of the rectum under saline is accomplished with the proctoscope.

CONCLUSIONS

Laparoscopic colectomy is now considered standard of care for colon cancer. Short-term and oncologic results have shown equivalency compared to open surgery, and the benefits of enhanced recovery are readily seen with the laparoscopic approach. Laparoscopic colon surgery does, however, require an advanced laparoscopic skill-set and in-depth knowledge of relevant anatomy.

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Laparoscopic total mesorectal excision

YULIYA YURKO AND TONIA M. YOUNG-FADOK

INTRODUCTION

Following the introduction of total mesorectal excision (TME) by Heald in 1979, the technique became the gold standard for treatment of middle and lower third rectal cancer with no anal sphincter involvement. The goal of this procedure is radical dissection and removal of the entire rectal mesentery to obtain adequate distal and radial margins with preservation of the sphincter function. Multiple factors are taken into account when making a decision regarding operative management. Thorough digital rectal examination should be performed to evaluate the distance of the tumor from the anal verge/dentate line/anorectal ring, involvement of the sphincter, tumor mobility, and involvement of the surrounding tissue. During the initial evaluation, we perform flexible sigmoidoscopy to assess the tumor and tattoo the distal margin of the lesion. If a patient has a complete response to the preoperative treatment, we are able to identify the level of dissection during the TME. Prior to surgery the patient should be fully informed about use of a temporary diverting ileostomy, as well as potential postoperative changes in bowel habits and lifestyle as a result of anterior resection syndrome.

A multidisciplinary approach is used for initial evaluation of a patient with newly diagnosed rectal cancer to determine the next step in treatment. If a patient requires preoperative neoadjuvant chemotherapy and radiation therapy, we then allow 10–12 weeks to recover before surgical intervention.

Preoperatively, every patient undergoes medical clearance, ostomy nurse consult, selective mechanical bowel preparation the day before the surgery, and chlorhexidine “shower.” Immediately preoperatively, there are orders for thromboprophylaxis and warming blanket. Every patient receives intravenous prophylactic antibiotics within 60 minutes of making the incision. All patients are enrolled in enhanced recovery protocols and receive detailed instructions regarding early nutrition, ambulation goals,

perioperative pain control, and anticipation of early discharge before the surgery. They are aware that early eating and early mobilization are part of their recovery plan.

Positioning

After induction and intubation, the patient is placed in modified lithotomy position using Allen stirrups with both arms padded and tucked (**Figures 89.1 and 89.2**). Convoluted utility pink foam pads and taping across the chest help to prevent the patient from slipping during the surgery. The patient’s head is also padded and stabilized to prevent the endotracheal tube being dislodged during the case. A Foley catheter is placed in sterile conditions. Digital rectal examination is performed prior to prepping to confirm the location of the tumor in regard to the anorectal ring (or anoscopy to



Figure 89.1 Patient is placed in modified lithotomy position using Allen stirrups with both arms padded and tucked.



Figure 89.2 Patient is placed in modified lithotomy position using Allen stirrups with both arms padded and tucked.

visualize a tattoo mark), and rectal irrigation is performed with iodine solution. Two video monitors are positioned, one on each side of the operating room table.

Port placement

A cutdown technique is employed to place a Hasson trocar (#1) in the supraumbilical position (**Figure 89.3**). A 12 mm trocar (#2) is placed in the planned marked site for the diverting loop ileostomy. Two 5 mm trocars are placed in the suprapubic and left lower quadrant positions (#3). An additional trocar can be placed, if needed, in the right or left upper quadrant lateral to the rectus muscle to assist with dissection.

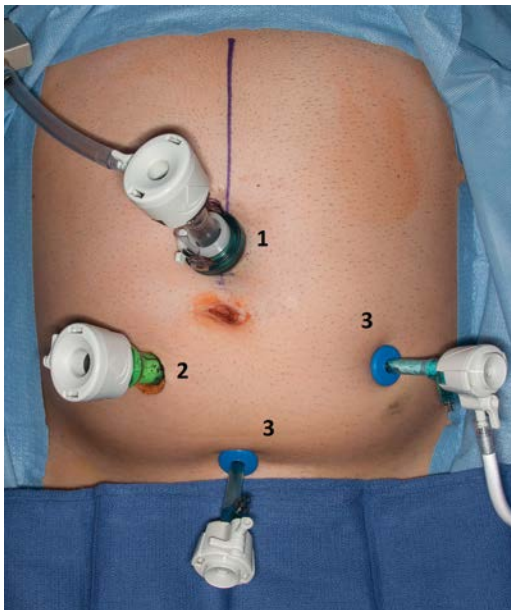


Figure 89.3 Port placement.

Instruments

Instruments include a 10 mm 30° scope, 5 mm 30° scope, laparoscopic bowel graspers, bipolar tissue sealing device, laparoscopic scissors, articulating linear endoscopic stapler with 3.5 mm staples, 28 mm circular stapler, and wound protector.

Procedural steps

1. Port placement and exploration. After placement of the Hasson trocar and creation of a pneumoperitoneum to 13 mm Hg, abdominal exploration is performed. If there are no signs of dissemination of the disease, then the remaining trocars are placed as previously described.
2. Sigmoid mobilization. The patient is placed in steep Trendelenburg position with the left side inclined up. The surgeon and camera assistant are on the patient's right side. Monitor #1 is in between the legs, and monitor #2 is next to the patient's left thigh. Using retractors through the suprapubic and right lower quadrant trocars, the small bowel is retracted from the pelvis and left abdomen to expose the sigmoid colon. A lateral-to-medial mobilization of the sigmoid and descending colon is commenced at the left pelvic brim along the white line of Toldt using endo shears and monopolar energy. Using a grasper in the left hand, the surgeon is continuously retracting the colon, medially exposing the operative plane. It is important to identify and dissect along the avascular plane between the mesocolon and retroperitoneum, leaving the white line of Toldt with the patient, and sweeping the mesocolon off Gerota fascia. The dissection is continued distally until the left ureter is well visualized crossing the iliac vessels, and proximally up to the splenic flexure.
3. Splenic flexure mobilization. The patient is placed in reverse Trendelenburg position, with the surgeon standing in between the patient's legs. Monitor #2 is positioned at the patient's left shoulder. The assistant gently retracts the colon using the right lower quadrant trocar. The surgeon starts mobilization of the splenic flexure using a bipolar tissue sealing device via the left lower quadrant trocar. The colon is retracted caudally and to the right, sweeping it off the retroperitoneum and tail of the pancreas. The omentum is elevated at the midportion of the transverse colon, and the lesser sac is entered. The omentum is dissected off of the distal portion of the transverse colon in order to complete splenic flexure mobilization.
4. Pelvic dissection. The surgeon moves to the patient's left side. The patient is placed in steep Trendelenburg position with a slight elevation of the left side up. After identification of the left ureter, the left pararectal peritoneum is scored and the presacral space is entered.

Rectal mobilization, using endo shears, continues lateral to medial keeping in the correct plane of dissection medial and anterior to the left ureter and iliac vessels in the avascular plane surrounding the mesorectum. The surgeon utilizes the suprapubic and left lower quadrant trocars. The assistant, utilizing the right lower quadrant port, performs rectal retraction away from the dissection. The left hypogastric nerve is identified and swept away from the rectum. Mobilization continues posteriorly toward the pelvic floor. Attention is then turned to the right. The right ureter is identified. The assistant retracts the rectum cephalad and to the left, and the surgeon scores the right pararectal peritoneum in order to enter presacral space and join with the dissection already performed from the left. Posterior and bilateral dissection continues until the pelvic floor is reached and the levator muscles are identified. The anterior peritoneal reflection of the rectovaginal or rectovesical pouch is incised while retracting the rectum cephalad and posteriorly. Careful dissection is performed down to the rectoprostatic fascia (Denovillier) until the seminal vesicles are visualized. In female patients, anterior dissection is performed in the rectovaginal septum. If the uterus obscures dissection, a straight needle, placed transabdominally, is used to suspend it to the abdominal wall below the suprapubic trocar. Once the rectum is circumferentially dissected, and before transecting the distal margin with an endoscopic linear stapler, a digital rectal exam is performed to ensure an adequate distal margin. An articulated linear endoscopic stapler is used, typically with either 3.5 or 4.8 mm cartridges.

5. Transection of the inferior mesentery artery (IMA). The surgeon moves back to the patient's right side. The patient is placed in steep Trendelenburg position with the left side up. Using a tissue sealing device, with an assistant retracting the sigmoid colon up and lateral through the left lower quadrant trocar, a window is created at the base of the sigmoid mesentery on the medial aspect just above the sacral promontory where the mesenteric window caudal to the IMA is seen. Dissection is continued cephalad from the medial approach up to the IMA, and windows are created in the mesentery on either side of the vessel. The IMA is isolated and divided using a tissue sealing device or a linear endoscopic stapler with a vascular 2.5 mm load. Both ureters are once again checked prior to division of the pedicle.
6. Resection and anastomosis. The supraumbilical port site incision is enlarged around the umbilicus, and the specimen is extracted using a wound protector, and resected with the appropriate proximal margin. A double-stapled end-to-end anastomosis is created typically using a 28 mm circular stapler. A pursestring suture is secured around a 28 mm anvil inserted in the cut edge of the proximal colon. The bowel is returned



Figure 89.4 Specimen retrieved during proctectomy for stage 3, lateral view.

into the abdomen, the fascial incision is closed, and the blunt port is secured again between two of the sutures. A pneumoperitoneum is reestablished. The circular stapler is gently inserted via the anus, and the spike is brought out adjacent to the staple line. The anvil is docked onto the stapler and before firing, the mesentery is examined to ensure it is correctly oriented, and there is surrounding tissue caught between the anvil and stapler. A loop of distal ileum is brought up to the abdominal wall to create a loop ileostomy.

The specimen should show an intact and continuous visceral mesorectal fascial envelope. As seen on the pictures of the specimen retrieved during proctectomy for stage 3 (T3N1M0) rectal cancer (**Figures 89.4 and 89.5**), the specimen has a smooth surface, without incisions or tearing. The



Figure 89.5 Specimen retrieved during proctectomy for stage 3, posterior view showing intact mesorectal envelope.



Figure 89.6 Response to neoadjuvant chemoradiation.

entire mesorectum is excised without coning and tapering toward the distal dissection. **Figure 89.6** shows the response to neoadjuvant chemoradiation.

Proper pathologic evaluation of the specimen provides important prognostic information. Current recommendations are to utilize a formal template to report the pathologic evaluation of the TME specimen (**Table 89.1**).

In the postoperative period an enhanced recovery protocol promotes early nutrition and mobilization starting on POD#0. During the perioperative period, multimodal analgesic regimens are used to decrease the use of opioids. Our current regimen includes bilateral transversus

Table 89.1 Colon/rectum resection reporting guideline

Synoptic final diagnostic template

Specimen	Lymph-vascular invasion
Procedure	Perineural invasion
Tumor site	Tumor deposits (discontinuous extramural extension)
Tumor size	Macroscopic completeness of mesorectum
Tumor histologic grade	Lymph nodes
Histologic grade	Response to treatment
Macroscopic tumor perforation	Additional findings
Margins	Pathology staging
Distance to mesorectal margin	

abdominis plane field infiltration (TAP block) with liposomal bupivacaine, performed by the surgeon at the beginning of the operation, patient-controlled analgesia pump if required, and scheduled nonsteroidal anti-inflammatory drugs (NSAID) and acetaminophen for the first 48 hours if appropriate. The laparoscopic approach helps minimize handling of the bowel, reduces tissue trauma and the systemic inflammatory response, reduces the need for opiate analgesics, facilitates early mobilization, and reduces the length of stay (**Video 89.1**).

VIDEO

Video 89.1 Laparoscopic total mesorectal excision (<https://youtu.be/qNu1twJnnY4>).

Laparoscopic treatment of inflammatory bowel disease

DANIEL SHOUHED, GUSTAVO FERNANDEZ-RANVIER, AND BARRY SALKY

ULCERATIVE COLITIS: LAPAROSCOPIC PROCTOCOLECTOMY

Indications for surgery

About 35% of patients with ulcerative colitis (UC) will require surgical treatment.¹ Restorative proctocolectomy with ileal-pouch anal anastomosis (IPAA) remains as the standard surgical treatment of choice for UC.²

The indications for elective surgery in UC vary, and depending on the severity of disease, socioeconomic factors, and patient preference, the treatment of chronic UC should be customized for each individual.³ Surgery may be indicated for patients who are refractory or unable to tolerate medications, or those with an increased risk of colon cancer, namely, those with dysplastic or adenomatous polyps or long-standing UC.⁴ In general, the benefits of laparoscopic surgery are largely known and include less postoperative pain, better cosmesis, and overall faster recovery from surgery.⁵ Interestingly, one study demonstrated a significantly higher rate of pregnancy after laparoscopic versus open IPAA, which makes the laparoscopic approach the method of choice in young women.⁶

The indications for emergent surgery include patients who develop colonic perforation, life-threatening gastrointestinal hemorrhage, and toxic megacolon. Similarly, those patients presenting with fulminant colitis refractory to medications will require emergency surgical intervention. In those cases where emergency intervention is needed, a total abdominal colectomy with end ileostomy is the most commonly performed procedure. As a staged procedure, at a later time when the patient has recovered, a completion proctectomy with IPAA can be performed.⁷

Preoperative preparation and port placement

Patients are placed on clear liquids for 24 hours before surgery and administered a gentle mechanical bowel prep the night before surgery, unless activity of disease precludes bowel prep. Perioperative antibiotics are administered, a Foley catheter is placed, and mechanical venous thromboembolic protection is placed on the legs. The patient is placed in lithotomy position, and the patient is prepped and draped, leaving access to the anterior abdominal wall and the perineum.

We prefer to use the Veress needle technique to insufflate and enter the peritoneal cavity, except in obese patients, where we use the Opti-View technique. Trocars are placed in all four quadrants. We also typically employ a 12 mm trocar either in the left lower quadrant or in the pre-marked ileostomy site in the right lower quadrant. This larger trocar is used for both stapling and mesenteric ligation with the 10 mm LigaSure device.

Mobilization and resection of the colon

We prefer to use a medial-to-lateral approach to dissection of the colon. However, on occasion, a lateral-to-medial approach is required. We believe it is important to be familiar with both approaches. The peritoneum of the mesentery is incised beginning with the ileocolic pedicle and carried up to the hepatic flexure. We typically use the 10 mm LigaSure device for ligation of the mesenteric vessels, although other surgeons prefer using the 5 mm LigaSure device. Care is taken to enter the plane between the mesentery and retroperitoneum, with definitive identification of the right ureter and the third portion of the duodenum prior to ligation.

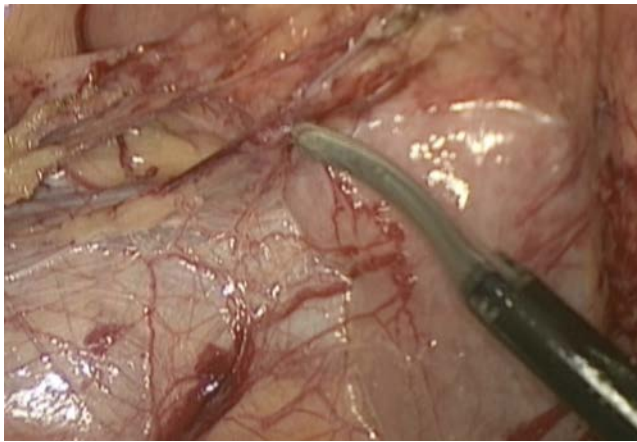


Figure 90.1 Proximal mobilization.

We will not routinely identify the right ureter in primary cases if the retroperitoneal fascia has been preserved and left intact; however, it is common to actually see the ureter through the fascial covering. The ileal mesentery has to be mobilized completely up to the pancreas so that there is no tension on the anastomosis (**Figure 90.1**).

The next step of the operation involves entering the plane between the left colon mesentery and retroperitoneum. This is initiated by incising the peritoneum overlying the presacral space. Once the left ureter, or fascia over it, has been identified, the mesentery is ligated inferiorly toward the rectum and superiorly toward the splenic flexure. We always score the mesentery first so that the energy device is placed directly on the blood vessel and not on the peritoneum over the blood vessel. We believe this decreases the incidence of mesenteric bleeding intraoperatively (**Figure 90.2**). As this is not cancer surgery, the dissection is kept high to minimize the risk of injury to the pelvic nerves. In women, the rectovaginal septum is dissected as low as possible. This

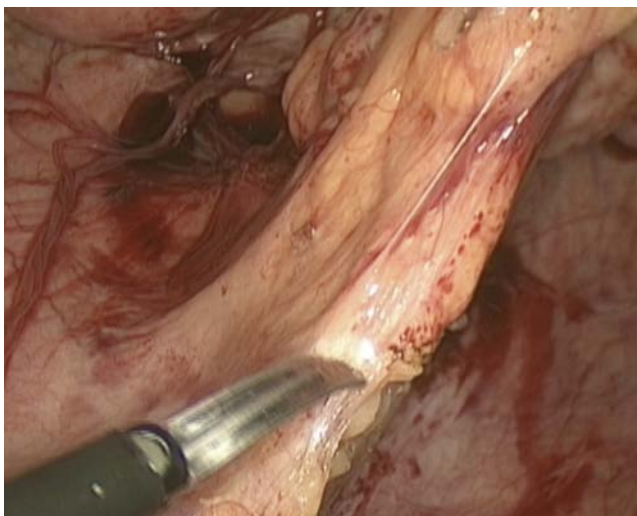


Figure 90.2 Scoring of rectosigmoid mesentery.

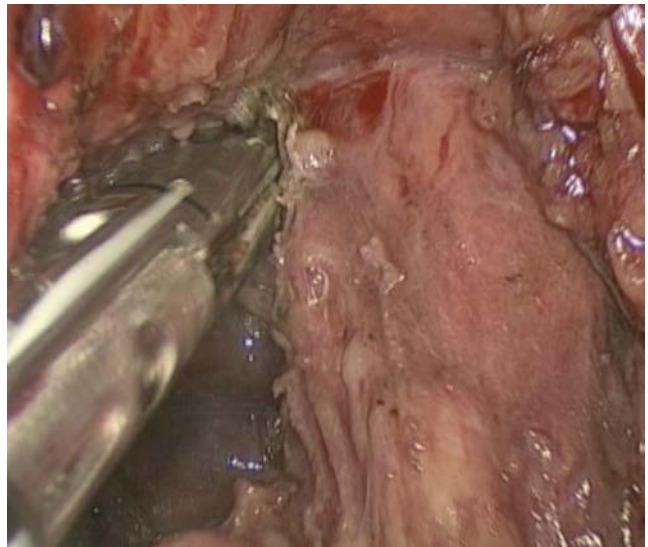


Figure 90.3 Rectovaginal cuff.

plane is easily identified (**Figure 90.3**), and the dissection is kept above the rectum as much as possible. Having an assistant keep a finger in the vagina at this point greatly simplifies this portion of the surgery. Superiorly, care is taken to identify and ensure safety of the left ureter and apply minimal tension on the spleen during division of the splenicocolic ligament. Once we have completed ligation of the mesentery, the lateral attachments of the colon are taken along the white line of Toldt with Endoshears and electrocautery. The transverse mesocolon is usually taken last using the same technique.

We always take the omentum as we feel leaving the omentum increases the risk of small bowel obstruction at a later date. It is important to make sure the terminal ileum is mobilized all the way to the pancreas so that no tension will be present on the J-pouch anal anastomosis. Additionally, it is important to go low on the rectal dissection (**Figure 90.4**). A critical error, which can occur with the laparoscopic approach, involves leaving a long rectal cuff, as this can increase the incidence of “cuffitis,” which can lead to pouch failure in the long term.

J-pouch creation

Once the colon and rectum have been fully mobilized and the mesentery has been ligated, the remainder of the case is performed open. We begin by making about a 5 cm muscle-sparing Pfannenstiel incision. The specimen is extracted through a wound protector, and the terminal ileum and rectum are transected with a 60 mm stapler. A 10 cm J-pouch is created in the standard fashion using a linear stapler.⁸ Once the J-pouch has been constructed and put back into the abdomen, the two ends of the bowel (EEA stapler) are visually controlled laparoscopically. It is important to make sure the mesentery is not twisted and that the pouch is properly



Figure 90.4 Short rectum.

oriented as in open surgery. The decision to make a complementary ileostomy or not is based on multiple factors and is not discussed in this chapter.

CROHN DISEASE: LAPAROSCOPIC ILEOCOLIC RESECTION

Indications for surgery

Surgical intervention for Crohn disease is mainly indicated for clinically symptomatic disease refractory to medical management.⁹ The most common indications are fibrostenotic disease with obstruction and penetrating disease with fistula(s) or abscess.¹⁰ Less common indications are growth retardation in children, free perforations, or adenocarcinoma. Clinically symptomatic Crohn disease may present with segments of the bowel actively inflamed demonstrating obstruction secondary to strictures, acute abdomen for bowel perforation, or when there is intra-abdominal abscess or fistula formation to adjacent organs. Recurrence of the disease and possible repeat surgery are very common events; therefore, bowel length preservation is of utmost importance for the long-term success and quality of life of those patients who present with Crohn disease. Strictureplasty is commonly utilized here, but its discussion is not appropriate for this chapter. In general, the laparoscopic approach is feasible and appropriate but may be associated with a longer operative time but a shorter length of stay and more rapid resolution of ileus.¹¹

Preoperative preparation

Patients with Crohn disease often present with some degree of malnourishment, dehydration, electrolyte imbalance, and/or acid-base disorders. Attention should be placed on

all of the above factors for optimization of the patient's medical condition prior to surgery. We do not use mechanical bowel preparation for small bowel resections but do use it for ileocolic resections. Recent data have supported "oral" antibiotics in the preoperative management in order to decrease the surgical site infection rate. Intravenous antibiotics are given 1 hour prior to surgery. There is controversy in stopping or continuing immunosuppressant medications prior to elective surgery. We do not stop them, as the data support no increase in complications with the use of preoperative immunosuppressive therapy. One of the real advantages of laparoscopic resections is that you do not have to administer stress doses of steroids postoperatively. In patients who are on steroids, they will receive one dose of 100 mg hydrocortisone at the time of surgery, and then they continue on their preoperative dosage on day 1. We do not pulse patients when the procedure is done laparoscopically. We have never had an Addisonian event in any case.

Ileocolic resection

In the operative room, the patient should be placed in supine position or in the modified lithotomy position with hips and knees slightly flexed if access to the anus is going to be required (i.e., ileo-sigmoid fistula) or if there is an intention for performing an intraoperative colonoscopy. The patient's arms should be tucked to the sides. The patient should be well secured to the operative room table for a safe position change during the procedure. The video monitor should be placed on the right side of the patient near the right lower quadrant of the abdomen (for ileocolic resection). A Foley catheter is routinely placed. Entry into the abdomen is surgeon's choice. A 5 mm 30° optic is placed infraumbilically. A 5 mm epigastric port, a 5 mm suprapubic port, and a 12 mm left lower quadrant port are placed. In general, medial-to-lateral dissection is performed, unless the inflammatory process does not allow the terminal ileum to be lifted off the retroperitoneum. The first step is to identify the anatomy, including the ileocolic vessels and the second portion of the duodenum. The small bowel is run throughout its entire length. The patient is placed in head down, right side up position. The first step is to elevate the ileocolic vessels with a 5 mm grasper placed through the epigastric 5 mm port. The peritoneum over the ileocolic vessels is divided with laparoscopic scissors. We prefer to use the 10 mm LigaSure bipolar energy device for the dissection. It goes through the 12 mm port in the left lower quadrant. The proper plane beneath the ileocolic vessels is identified (**Figure 90.5**). This is required for a medial-to-lateral dissection. A technical point is to release tension on the ileocolic while applying the energy (**Figure 90.6**). Once divided, the retroperitoneal fascia is identified. The dissection stays just above the fascia moving medial to lateral. The gonadal vessels and ureters are below the retroperitoneal fascia. This plane must be identified or conversion to open is appropriate at this stage. The ileal vessels are divided with the 10 mm LigaSure up to the



Figure 90.5 Proper plane of dissection.

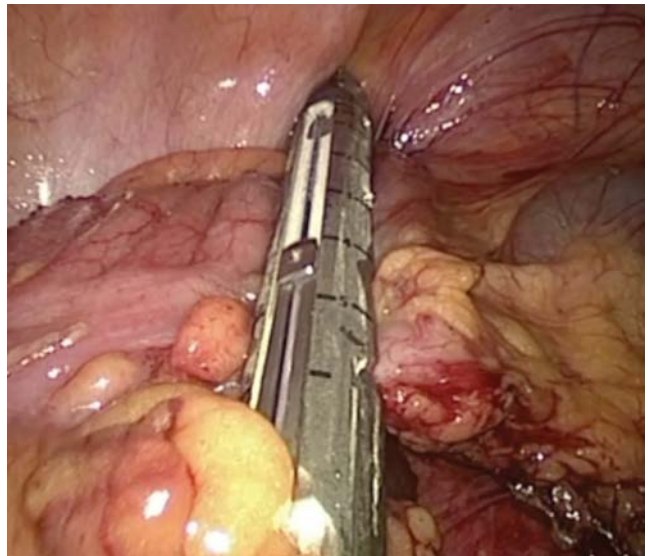


Figure 90.7 Intracorporeal stapling of colon.



Figure 90.6 Ligasure device.

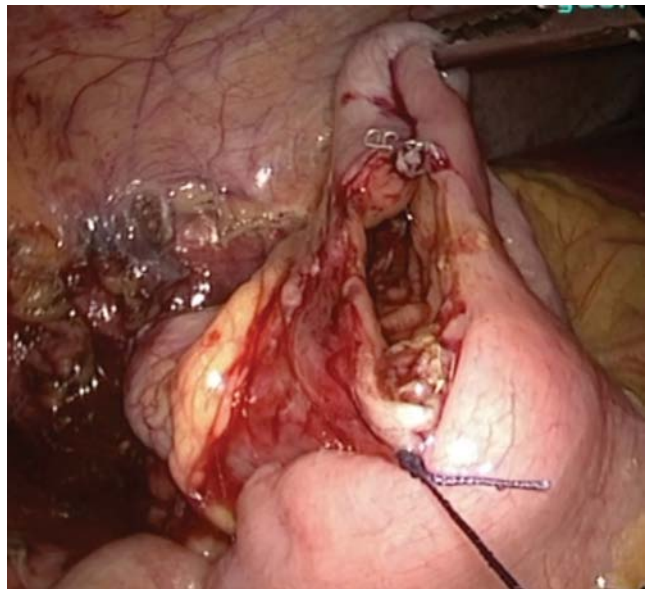


Figure 90.8 Common opening.

bowel wall. The mesentery to the ascending colon is divided as well. The lateral attachments are divided with electrocautery scissors. The intestine is transected with a 60 mm endoscopic GIA stapling device (**Figure 90.7**). Ordinarily, one cartridge is required for transection. It is important to place the stapler at 90° angles to the bowel wall. The specimen is “stored” in the pelvis for extraction later in the procedure. The bowel is aligned in an isoperistaltic fashion. The base of the mesentery is checked for proper alignment. If this is followed, the two ends of the bowel cannot be twisted. An enterotomy and a colotomy are made under direct vision with the 5 mm hook electrode with cutting current. It is important to ensure that the lumen of the bowel is identified. If the ileum is obstructed and dilated, a laparoscopic

bulldog clamp can be applied to prevent spillage of intestinal contents. A 60 mm GIA stapler is placed inside each enterotomy, properly positioned, and activated. The stapler is retracted into the 12 mm port, and the port and stapler are removed together. An assistant puts a finger in the 12 mm hole to prevent leakage of pneumoperitoneum. The 12 mm port is cleaned and replaced. The common enterotomy is then closed in two layers: inner layer is running 2–0 Vicryl, and the outer layer is running 3–0 Prolene (**Figures 90.8 and 90.9**).^{12,13} The mesentery defect is closed. The specimen is removed through a small Pfannenstiel incision with a wound protector.

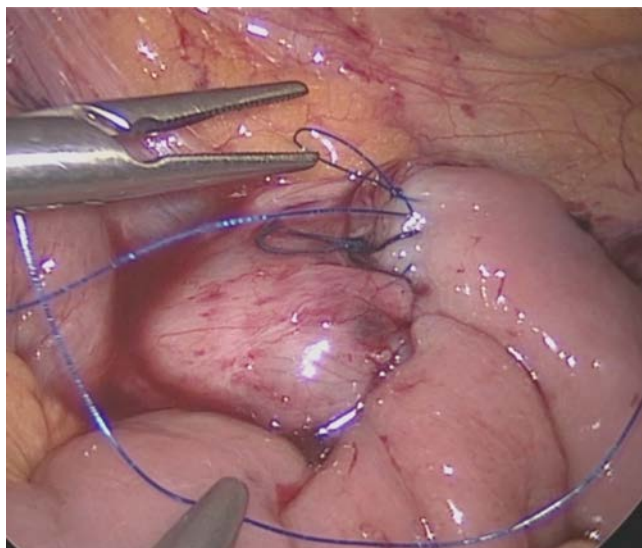


Figure 90.9 Completed anastomosis.

Postoperative management

The patient is offered clear liquids the day of surgery. Pain medications include Percocet and Toradol, and the patient is encouraged to be out of bed the evening of surgery.

Subcutaneous heparin is begun the day after surgery, and the Foley catheter is removed on postoperative day 1. A solid diet is begun when bowel function occurs, usually on postoperative day 2 or 3.

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Robotics in colon and rectal surgery

DEBORAH M. NAGLE

INTRODUCTION

The benefits of minimally invasive techniques have been demonstrated in multiple surgical subspecialties, and several randomized control trials¹⁻³ have observed these benefits in laparoscopic colorectal surgery as well. These include reduced intraoperative blood loss, postoperative pain and ileus, shorter length of hospital stay, and improved cosmesis.⁴ Moreover, these studies have also confirmed comparable oncologic outcomes when compared to open surgery. As such, laparoscopic colorectal surgery has gained popularity and is now considered a safe alternative to open procedures.^{5,6}

However, laparoscopic surgery is fraught with a long learning curve, as well as multiple inherent limitations that include reliability on assistant-controlled camera visualization, two-dimensional imaging, limited dexterity, diminished tactile sense, and poor ergonomics. These limitations are particularly pertinent when operating within the confines of the pelvis for rectal dissections.^{5,6}

Robotic surgery, though slow to be adopted in the field of colorectal surgery, offers improvements on many of these limitations while maintaining the advantages of a minimally invasive technique. As such, there has been a steady increase in robotic use in the field, though it has been mainly for rectal surgery.^{5,6}

CAMERA CONTROL AND IMAGING

The robotic system includes an operator-controlled stabilized camera that offers a three-dimensional view with available 10-fold magnification if desired. This results in an exceptionally stable and clear view of the operative field.⁵⁻⁷

DEXTERITY

One of the major limitations of laparoscopic surgery is only having 4° of motion as compared to the 7° available with the human wrist. This is further exacerbated by the paradoxical intraperitoneal instrument movements due to the fulcrum effect of the abdominal wall, and the use of long instruments serves to magnify physiologic hand tremors. The robotic arm seeks to address these with the use of multiarticulated tips that allow the operator to reclaim the manual dexterity of the human wrist, resulting in a regained 7° of movement, 180° articulation, and 540° rotation. This is further improved upon by tremor filtering and motion scaling (to either up- or downscale movements), allowing for exceptional precision and control of movement.^{5,6,8,9}

ERGONOMICS

Laparoscopic surgery often involves irregular stances and arm positioning in order to achieve the desired instrument movements. This may result in operator injury and/or fatigue.^{5,10} Robotic surgery reduces this physical strain as the surgeon sits at a console with his or her arms comfortably resting on pads, and hand motions are similar to that of an open procedure.¹¹

LEARNING CURVE

Laparoscopic colorectal surgery has quite a lengthy learning curve,¹² and it has been argued that given the robot's ability to transfer the motion of the surgeon's hands to the instruments so as to mimic an open procedure, the learning curve at the console is relatively shorter.⁵

DISADVANTAGES OF ROBOTIC SURGERY

Length of procedure

It has been well reported that robotic procedures increase the length of procedures over their laparoscopic equivalents. One of the major causes of this is the fact that robotic towers require docking in specific and quite particular positions so as to avoid robotic arm collisions and allow the best exposure and access for an operation. This, along with the undocking process, can be quite a time-consuming process. This is further exacerbated given that, once docked, use of the robot only allows access to one compartment in the abdomen at a time, and so access to different compartments often requires repeated lengthy docking and undocking processes.

Another major concern that has been raised related to the time required to undock the robot is that if immediate conversion to an open procedure is necessary for major bleeding, the time taken to undock the robot could significantly affect the situation. However, it should be noted that the conversion rate for robotic procedures is significantly less than that for laparoscopic procedures. This may reflect the sentiment that with the improved visualization and instrument control, the surgeon is able to handle more difficult operations and deal with urgent situations such as bleeding without converting to an open procedure. However, it may also reflect a patient selection bias with less-complicated procedures being performed with the robot while it is still being learned in the field.

Lack of haptic feedback

One of the most significant disadvantages of robotic surgery is the lack of both tactile sensation and tensile feedback. This results in a potential increased risk of tissue damage during retraction or dissection and suture disruption while stitching with the robotic arms. These risks can be decreased by learning to use visual cues such as tissue tenting to approximate tension. However, it requires experience and increased attentiveness and care when handling tissue. Of note, in a systematic review of robotic colorectal surgery, iatrogenic colonic traction injuries were not reported in any of the studies included, and there has been no note of complication increases in robotic surgeries as compared to their laparoscopic counterparts.

Cost

The price of one da Vinci robotic system is over \$2 million. The maintenance of the system averages \$500,000 per year. Moreover, the cost of the disposable instruments used with each case averages \$2,000. This significant initial capital and running cost of the da Vinci robotic system is likely the main reason that robotic surgery has been slow to be adopted in many countries. While laparoscopic surgery also

increases intraoperative costs as compared to open surgery, it results in an overall cost reduction due to a reduction in postoperative length of stay as well as postoperative complications. Robotic surgery does not offer any such advantages over laparoscopic surgery, as discussed later. Future platforms from other companies may be able to provide more affordable systems, and with improved instrument manufacturing and newer systems requiring less maintenance, the running costs may decrease. However, without any benefit in reduction of postoperative care over laparoscopic surgery, there is no reason to presume that it will add any cost advantage.

BRIEF HISTORY OF ROBOTIC SURGERY IN COLORECTAL SURGERY

The first colorectal robotic surgery was performed in 2001. Only a handful were subsequently reported in the following year. In 2004, D'Annibale et al. reported that they could achieve equivalent operative and postoperative results compared to conventional laparoscopic surgery, based on a series of 53 robotic colorectal cases performed during the preceding 3 years. In 2006, Pigazzi et al.¹¹ first reported the concept of robotic total mesorectal excision for rectal cancer as feasible, and in 2007 they compared a series of six robotic-assisted low anterior resections with total mesorectal excision to conventional laparoscopic techniques and concluded that the operative and pathological data, as well as complications and hospital stay, were similar between the two groups. Around the same time, the first prospective randomized trial was launched by Baik et al.⁹ comparing robotic and conventional laparoscopic low anterior resections, also demonstrating the feasibility and safety of robotic resection with equivalent mesorectal excision grades. Since then, robotic colorectal surgery, though slow to be adopted in the field, has mainly demonstrated its niche in rectal surgery, where improved visualization and instrument dexterity offer advantages over conventional laparoscopy.

Though a few platforms have been identified and there are many in the works, the only one approved by the U.S. Food and Drug Administration (FDA) and the most widely used is the da Vinci robotic system (Intuitive Surgical Inc., Sunnyvale, California). This robotic surgical system consists of three main parts: the robotic tower with robotic arms, the video tower, and the surgeon's console.

The surgeon sits at the console and operates the robotic arms using mechanical graspers attached to the thumb and index and middle fingers, while viewing the operative field through a pair of binoculars. Foot pedals allow the operator to switch the control of different robotic arms, temporarily uncouple the control of the graspers from the robot so as to reposition his or her hands, adjust the zoom scale (up to 10-fold magnification), and activate the electrocautery. The robotic interface allows for motion scaling of 1:1, 3:1, or 5:1 and physiologic tremor filtering, and it performs intuitive movement between the operator's hands and the robotic arms.

The video tower, similar to that of a laparoscopic tower, supports the video camera control boxes, the light sources, the insufflators, and a video monitor.

On the robot side, there is one endoscopic arm and two (da Vinci) or three (da Vinci-S, da Vinci-Si, da Vinci Xi) working arms. The endoscopic camera consists of two 5 mm telescopes within a 12 mm housing, which each project separate images to the console, providing a true three-dimensional view of the operative field. The working arms have special multiarticulated tips that provide endowrists, as described previously, allowing for precise work.

Image brightness

If the image is too bright, use the brightness slider on the touchpad to decrease it to the desired level. If the image is too dark, proceed by removing the endoscope and cleaning both ends as well as cleaning the camera head lens. If still too dark, try another endoscope. If this does not work to correct the problem, power off the camera control unit (for da Vinci standard or S model) or power off the entire system (for da Vinci Si) and change out the camera head and camera cables. If the problem persists, contact technical support.

Poor or blurry image

If you are having a problem with the image, start by adjusting the digital zoom setting from the touchpad to see if that alleviates the issue. If not, you can then attempt to refocus the image from either the focus controller or the camera head and then from the surgeon console focus pedal (depending on the da Vinci model). If you still cannot focus, change out the endoscope. If this does not work to correct the problem, power off the camera control unit (for da Vinci standard or S model) or power off the entire system (for da Vinci Si) and change out the camera head and camera cables. Once powered back on, refocus the image and perform black and/or white balances, as well as three-dimensional (3D) calibration. If still poor or blurry, you should contact technical support.

Flickering image

If the image is flickering, you should initially check for cautery interference. If it is only happening during utilization of electrocautery, move the electrosurgical unit and its cables away from the Vision Cart and the camera cables. Try another endoscope if that fails. If this does not work to correct the problem, power off the camera control unit (for da Vinci standard or S model) or power off the entire system (for da Vinci Si) and change out the camera head and camera cables. If the problem persists, contact technical support.

Missing image in one or both eyes

If you are missing images in either one eye or both eyes, start by checking the default settings on the camera control unit and restore the default settings. If this does not work to correct the problem, redo the white balance and/or black balance procedures. If still no image is seen, ensure that all camera cable connections are secured to both the camera control unit and the camera head. If the cable cannot be tightened any more but shaking it affects the picture, replace the cable. Finally, you can try replacing the camera head. If none of this works, you should contact technical support.

PATIENT SELECTION

The benign and malignant disease processes that are indications for laparoscopic and open colorectal surgery are also indications for robotic procedures. Ideal patients are similar to those for laparoscopic surgery and include otherwise healthy individuals who are close to their ideal body weight and who have not had previous operations. For some patients, robotic surgery may actually be advantageous over laparoscopy. This is particularly true in obese patients, with low-lying rectal pathology or with narrow pelvic inlets, as laparoscopic rectal surgery has often been associated with high intraoperative conversion rates—especially in the previously mentioned conditions.

Similarly, contraindications to laparoscopic colorectal surgery, such as life-threatening pathology (perforation or peritonitis), also apply to robotic surgery. Moreover, there are several relative contraindications to the robotic approach that include patients with a prior history of peritonitis or with multiple previous surgeries. Such patients may benefit from a hybrid approach, with laparoscopic lysis of adhesions prior to robotic assistance. Patients with complex anatomy due to their disease process, such as Crohn disease with fistulae and/or obstruction, may not be amenable to proper identification of landmarks to proceed with safe surgery. Further, patients with large tumors involving adjacent structures or organs should be approached from the standpoint of an oncologic resection and may not be appropriate for robotic intervention.

PROCEDURES

Right colectomy

PATIENT POSITIONING

The patient is placed in a supine position with the iliac crest positioned over the midtable joint. The patient is secured on either a beanbag or with tape so as to prevent sliding. The arms are tucked alongside the body to allow space for the robot and assistant, especially on the right side. A urinary catheter, along with optional nasogastric or orogastric tube, is placed. The patient is then positioned

in reverse Trendelenburg with right side up and remains this way throughout the case. The table can be flexed at the midjoint (approximately 15°) to lower the patient's legs, preventing external collisions of the robot arms with the patient.

PORT PLACEMENT

Five ports are placed as demonstrated in [Figure 91.1](#). After the induction of pneumoperitoneum using a Veress needle in the left upper quadrant, a 12 mm port is placed to the left and slightly inferior to the umbilicus for the robotic camera. An 8 mm working port is then placed in the left upper quadrant, ~2–3 cm lateral to the midclavicular line and ~3–4 cm inferior to the costal margin. A second one is inserted in the midline, inferior to the umbilicus maintaining approximately 8–10 cm from the camera port. This port can be used for specimen extraction or extracorporeal anastomosis if desired. The third working port is also placed in the left upper quadrant about 2–3 cm subxiphoid and ~4 cm to the left of midline. A 5 mm assistant port is placed in the left-lower quadrant, slightly lateral to the midclavicular line and slightly inferior to the line between the umbilicus and iliac spine. These ports should be separated from each other by at least 8–10 cm (measured after insufflation) so as to prevent robotic arm collision.

ROBOT POSITIONING

The robot tower can be moved into position for docking at the level of the patient's right upper quadrant at an angle of approximately 15° relative to the operating table. The robot should be docked with the robotic endoscopic arm in the neutral position brought into position along this axis toward the camera port.

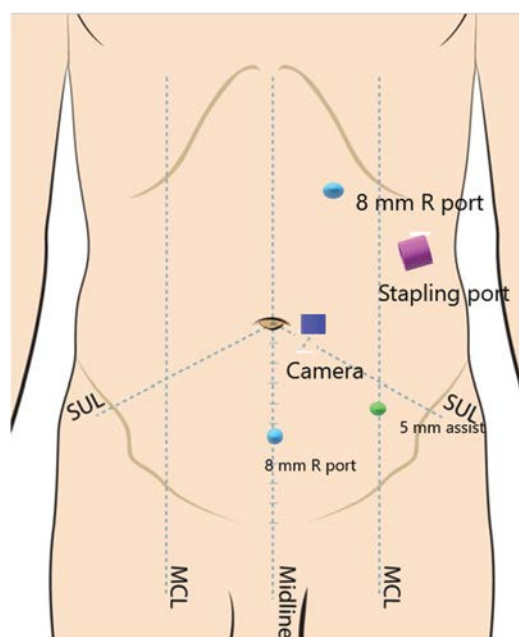


Figure 91.1 Right colectomy port placement SL.

TECHNIQUE

Using a hook cautery or scissors on the left robotic arm and a bipolar fenestrated grasper on the right robotic arm, a standard medial-to-lateral or lateral-to-medial approach can be used, depending on the surgeon's preference. For the medial-to-lateral technique, control of the ileocolic pedicle is first achieved. This is done by retracting the cecum laterally to identify the pedicle, and the ileocolic artery can be carefully dissected out close to its origin. The artery can then be transected using a vascular endostapler or suture-ligation with the robotic system. As with the conventional laparoscopic procedure, the colon can be mobilized off the retroperitoneum in a medial-to-lateral fashion, taking care to avoid the duodenum. Beginners to robotic surgery sometimes prefer the lateral-to-medial technique as it more closely resembles open surgery. For this technique, the cecum should be grasped and retracted medially initially and the peritoneum incised in the right pericolic gutter. Following along this avascular plane, the entire right colon can be mobilized up to the hepatic flexure. The right gonadal vessels and the right ureter should be identified and preserved. This can then be followed by control of the ileocolic pedicle, as described.

The robotic arms should then be temporarily undocked so that the patient can be placed into reverse Trendelenburg, exposing the hepatocolic ligament by causing the omentum and transverse colon to shift caudally. This allows the best exposure for mobilization of the hepatic flexure. By retracting the transverse colon inferiorly, both the hepatocolic and gastrocolic ligaments can be divided with the help of bipolar cautery.

Once mobilization of the right colon is complete, it can be resected using a linear GIA stapler via the assistant port and the mesentery divided using bipolar cautery. The resected right colon can then be set aside and an intracorporeal hand-sewn ileocolonic anastomosis performed. The resected colon can then be removed via either a Pfannensteil incision or a mini-laparotomy. Alternatively, following mobilization, the robot can be undocked and the incision for the camera port extended superiorly to create a small midline mini-laparotomy. The mobilized right colon can then be exteriorized through this incision and resected extracorporeally. A conventional side-to-side ileocolic anastomosis can then be created in the usual open fashion.

LEFT COLON PROCEDURES

Patient positioning

The patient should be placed on the operating room table either on a beanbag, or with appropriate padding to maintain support in a low lithotomy position. A urinary catheter, along with optional nasogastric or orogastric tube, is placed.

To begin for inferior mesenteric artery (IMA) division and rectal dissection, the patient is placed in a steep

Trendelenburg position, and the robot is docked over the left hip to the three lower abdominal ports.

For splenic flexure mobilization, the patient is placed in the reverse Trendelenburg position (30°–45°) with his or her left side up (15°–30°), and the robot is brought over the patient's left shoulder and attached to the three upper abdominal ports.

Port placement

Five ports are inserted (four robotic and one assistant port). A 12 mm port is placed at the umbilicus for the camera. An 8 mm robotic port is then placed in the right midclavicular line, slightly inferior to the camera port. Another 8 mm robotic port is placed in the left midclavicular line at a horizontal position from the camera port at the level of the umbilicus and a third 8 mm robotic port is placed in the left lateral lower quadrant off of the anterior superior iliac spine. A 12 mm port is placed in the right lower quadrant two fingerbreadths cephalad and two fingerbreadths medial off the anterior superior iliac spine. This port will be the assistant's port. These ports should always be separated from each other by at least 10 cm so as to prevent robotic arm collision.

Robot positioning

For division of the IMA/inferior mesenteric vein (IMV) pedicle, as well as sigmoid colon and rectal dissection, the robot is docked over the left hip, at an angle of approximately 15°–30° to the bed, allowing for the endoscopic arm to dock in a direction parallel to the bed, and looking directly into the pelvis. The first robotic arm attaches to the right lower quadrant 8 mm port. The second robotic arm attaches to the left lower quadrant port and the third arm to the left lateral port.

For splenic flexure mobilization, the robot is brought over the patient's left shoulder at an angle of approximately 15° to the bed and attached to the three upper abdominal ports. The first robotic arm attaches to the left lower quadrant 8 mm port. The second robotic arm attaches to the right lower quadrant port, and the third arm is left detached.

Technique

Procedures of the left colon involve a combination of the steps described as follows. For a sigmoid colectomy, IMA and IMV ligation as well as sigmoid and descending colon dissection, splenic flexure mobilization, and specimen extraction are all required. For a low anterior resection (LAR), the preceding plus or minus the splenic flexure mobilization but adding in the mesorectal excision are required. For an abdominoperineal resection, all of the preceding are required, but the

specimen extraction is different and no reanastomosis is required (but rather end colostomy formation).

INFERIOR MESENTERIC ARTERY AND INFERIOR MESENTERIC VEIN LIGATION

The first part of all of the procedures involving the left colon involves exposure and vascular ligation of the IMA.

The abdominal cavity is explored laparoscopically and the small bowel loops cleared from the pelvis to expose the IMA. The patient is then placed in steep Trendelenburg position with the left side up (0°–10°), and the robot is docked in the left lower quadrant, over the left hip, obliquely along the line from the camera port to the anterior superior iliac spine. The camera arm is docked to the 12 mm umbilical port. The first arm is docked to the 8 mm right lower abdominal midclavicular port. The second arm is docked to the left midclavicular 8 mm abdominal port. The third arm is docked to the left lower quadrant port. The remaining 12 mm right lower quadrant port is used by the assistant to retract the sigmoid mesocolon anteriorly, placing the IMA on stretch.

A 30° scope is used. In the first robotic arm, a monopolar curved scissors or hook electrocautery is placed and functions as the surgeon's right hand. A bipolar fenestrated grasper is placed in the second robotic arm as the surgeon's left hand, and another grasper is placed in the left lower quadrant as the surgeon's second left hand in the third robotic arm. The surgeon can engage the clutch pedal to toggle between the first left and second left robotic arms.

Dissection of the IMA and IMV is performed using a medial-to-lateral technique. To start, the sigmoid mesocolon over the IMA is retracted upward by the assistant, and with the assistance of some additional mild traction by the fenestrated forceps, the peritoneum to the right of the base of the IMA is opened with the monopolar scissors to start the dissection. The dissection is continued, working proximal toward and over the base of the IMA, taking care to preserve the periaortic hypogastric nerve plexus. The inferior mesenteric pedicle should be dissected out from both medial and lateral sides, and as with laparoscopic surgery, the left ureter and gonadal vessels identified in the resulting window and preserved. The pedicle can then be divided using either a robotic vessel sealer placed into the first robot arm in place of the monopolar scissors or laparoscopic clips, a 10 mm LigaSure or EndoGIA 2 mm vascular stapler introduced through the 12 mm assistant port. Care should be taken to ensure that the ureter is not being pulled into the area of division.

MESORECTAL EXCISION AND RECTAL DIVISION

In the same robotic configuration, the second and third robotic arms under control of the surgeon's left arm will be used for retraction of the bladder/vagina/prostate or

rectum as needed. The first robotic arm will remain as the surgeon's right hand and main tool for sharp dissection with either a monopolar scissors or hook electrocautery. With the rectosigmoid retracted cephalad by the assistant, the fenestrated grasper retracts the rectum anteriorly, exposing the posterior mesorectal fascia. The avascular plane along Waldeyer fascia, between the rectal fascia propria and presacral parietal fascia, is then dissected sharply with the monopolar scissors all the way inferiorly to coccyx. The posterior plane through the loose areolar tissue between the mesorectum and the presacral plexes of veins is developed. The ureters are lateral to the dissection plane and the inferior hypogastric nerves, and more distally, the pelvic nerve plexus lies posteriorly and should be identified and preserved. Dissection is continued inferiorly and in a medial to lateral direction down to the levator ani. Once sufficiently low on the rectum from the inferior and medial plane, left lateral dissection of the lateral attachments of the sigmoid colon down the rectum along the white line of Toldt can be performed while the rectum is retracted to the right by the assistant. Finally anterior dissection is performed with the third arm grasper providing upward retraction of the bladder/vagina/prostate, while the fenestrated grasper provides posterior retraction of the rectum. Once the entire rectum is mobilized, the assistant uses a roticulating 60 mm endoscopic 3.5 GIA stapler to divide the rectum.

LEFT SIGMOID AND DESCENDING COLON DISSECTION

With the robotic arms in the same configuration, the dissection can then be taken superiorly in either a medial-to-lateral or lateral-to-medial fashion, similar to that done laparoscopically. In the medial-to-lateral form, dissection is carried upward toward the ligament of Treitz, developing the space between the mesocolon and Gerota fascia bluntly outward. The dissection continues superiorly over the pancreas until the lesser sac is entered and medial dissection continues as far laterally as possible until the left colon is separated from the retroperitoneum. Lateral detachment can then be performed while the assistant provides medial retraction. The fenestrated grasper can be used to provide lateral countertraction. The lateral dissection continues to the mid-descending colon and up to the splenic flexure as far as the limit of the robotic arms will allow.

SPLenic FLEXURE MOBILIZATION

Mobilization of the splenic flexure requires repositioning of the patient and redocking of the robot. With the patient repositioned in reverse Trendelenburg position (30°–45°) with the left side up (15°–30°), the robot is brought over the patient's left shoulder this time and attached to the three upper abdominal ports. The camera is docked to the 12 mm

umbilical port. The first arm is docked to the left abdominal midclavicular 8 mm robotic port. The second arm is docked to the right midclavicular abdominal 8 mm robotic port. The right lower 12 mm port is continued to be used as the assistant's port.

A robotic fenestrated grasper is placed in the second robotic arm and used to retract the proximal descending colon medially as the assistant uses a bowel grasper to retract the middescending colon medially. Robotic cauterized scissors or hook cautery is placed in the first robotic arm and used to mobilize the lateral peritoneal attachments of the proximal descending colon up and around the splenic flexure, dividing the renocolic and splenocolic ligaments from the distal transverse colon. A robotic vessel sealer device can then be placed into the first robotic arm and used to divide and detach the greater omentum from the transverse colon. To aid in this endeavor, anterior and cephalad retraction of the omentum can be provided with the fenestrated grasper, with the assistant providing caudal retraction of the transverse colon. Medial-to-lateral dissection of the distal transverse colon from the retroperitoneum and Gerota fascia can then be completed in this configuration as well, as far proximal as the ligament of Treitz.

SPECIMEN EXTRACTION AND REANASTOMOSIS (FOR SIGMOID COLECTOMY OR LOW ANTERIOR RESECTION)

Prior to specimen extraction, once the rectum has been divided and the splenic flexure mobilized (if needed), one must verify that all attachments of the rectosigmoid are completely divided and the descending colon is free to easily reach the pelvis. The robot is then undocked and moved away from the operating room table for the remainder of the case.

The umbilical incision is enlarged to approximately 4 cm. A wound protector is placed, and the rectosigmoid is delivered through the umbilical wound. A pursestring suture device is placed on the descending colon, and the colon is transected. The specimen is sent to pathology, and an EEA anvil is placed into the descending colon. The descending colon is then dropped back into the abdominal cavity. The 12 mm port is placed back through the wound protector and umbilical tape wrapped and tied around it to allow reinstitution of pneumoperitoneum. Using conventional laparoscopic instruments, the EEA is passed transrectally, and the two ends of the stapler are joined together. Being certain the colon is not twisted, the EEA is closed. The anastomosis is then performed and the donuts are inspected to be sure there are two complete rings. The anastomosis is tested by submerging it in a pool of irrigation fluid as a noncrushing bowel grasper is placed on the descending colon. The integrity of the anastomosis is confirmed by rigid sigmoidoscopy or rectal insufflation to ensure there is no air leakage from the anastomosis.

All irrigation, pneumoperitoneum, and ports are then removed. The fascia of the 8 and 12 mm ports are closed with 0-vicryl suture and the skin incisions closed with 4-0 Monocryl suture.

SPECIMEN EXTRACTION (FOR ABDOMINOPERINEAL RESECTION)

Once a point of proximal transection is determined, it can be divided by the assistant using a roticulating 60 mm endoscopic 3.5 GIA stapler. Prior to specimen extraction, one must verify that all attachments of the rectosigmoid are completely divided and the end of the descending colon is free to easily reach the anterior abdominal wall at the chosen site of end colostomy. The robot is then undocked and moved away from the operating room table for the remainder of the case.

The remainder of the case is as described for both laparoscopic and open abdominoperineal resection procedures. The colostomy can be matured and attention turned to the patient's perineum. An elliptical incision encompassing the anus and sphincter muscles is performed. The Lone Star retractor can be brought into the field to provide retraction. Dissection is carried out posteriorly through the anococcygeal ligament, and access is gained into the perineal cavity, above the sacrum. The levator muscles on either side are dissected free of the rectum, and anteriorly, the dissection is carried through the transverse perineal muscle. The specimen is then delivered through the anus.

Closure of the perineal wound is begun approximating the levator muscles from posterior to anterior with 2-0 Vicryl interrupted sutures. Subcutaneous tissue is approximated using 2-0 Vicryl interrupted sutures, and the skin is approximated using 3-0 Vicryl horizontal mattress sutures.

HYBRID AND SINGLE-STEP TOTAL ROBOTIC TECHNIQUES

Other strategies have been described for left colon resections in addition to the one previously described, including a hybrid technique and, recently, a single-stage robotic technique.

Hybrid technique

One of the disadvantages of the robot is that once docked in a certain position it is difficult to obtain access to multiple parts of the abdomen. As can be seen from the techniques previously described, anything that requires splenic flexure mobilization requires that the robotic cart be repositioned. This obviously increases operative time.

To eliminate that, some surgeons prefer a hybrid technique that involves standard laparoscopic mobilization of

the left colon and splenic flexure and sometimes also the inferior mesenteric vessels, followed by robotic dissection within the pelvis for the total mesorectal excision part of the operation.

Single-stage robotic technique

PATIENT POSITIONING

The patient is placed in a modified lithotomy position with the legs apart on stirrups. The patient is secured on either a beanbag or with tape so as to prevent sliding. The arms are tucked alongside the body to allow space for the robot and assistant. A urinary catheter, along with optional nasogastric or orogastric tube, is placed. Once the ports are placed, the patient will be positioned in deep Trendelenburg with left side up and remains this way throughout the case.

PORT PLACEMENT

Six ports are placed as demonstrated in **Figure 91.2**. After the induction of pneumoperitoneum using a Veress needle, a 12 mm port is placed to the right of the umbilicus for the robotic camera. An 8 mm port is then placed at McBurney point. A second one is inserted in the right subcostal area on the midclavicular line. The third is placed in the left upper quadrant about 1–2 cm above the camera port, and the fourth is inserted in the left lower quadrant about 1–2 cm lateral to the midclavicular line. These ports should be separated from each other by at least 10 cm so as to prevent robotic arm collision. A 5 mm trocar is placed in the right flank area along the anterior axillary line at the umbilical level as the assistant port.

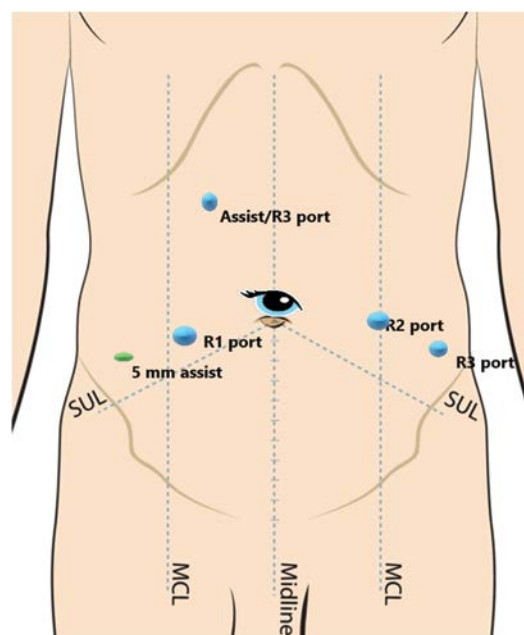


Figure 91.2 LAR/left placement SI.

ROBOT POSITIONING

The robot tower can be moved into position for docking at the level of the patient's left hip at an angle of approximately 30° relative to the operating table. The exact alignment of the robot can be estimated using a line connecting the left anterior superior iliac spine and the umbilical camera port. The robot should be docked with the robotic endoscopic arm in the neutral position brought into position along this axis.

TECHNIQUE

Similar to the procedure previously described, the procedure is divided into parts. The first part of the procedure involves exposure and vascular ligation of the IMA, followed by medial-to-lateral mobilization of the sigmoid and descending colon to the splenic flexure. The second part involves the actual total mesorectal excision (TME). The difference is that this technique involves repositioning the robotic arms between the two steps rather than moving the entire robotic cart.

The patient is tilted to the right and placed in the Trendelenburg position. The abdominal cavity is explored laparoscopically and the small bowel loops cleared from the pelvis to expose the IMA. The robot is then docked at the left lower quadrant, as described.

A 30° scope is used. The first robotic arm attaches to the right lower quadrant 8 mm port, and a monopolar curved scissors or hook electrocautery is placed and functions as the surgeon's right hand. The second robotic arm attaches to the right upper quadrant 8 mm port, and a Maryland grasper is placed as the surgeon's left hand. The third arm is placed in the left upper quadrant as the surgeon's second left hand, and a bipolar fenestrated grasper is used.

The first part of the procedure involves mainly the first robotic arm and third robotic arm, with help from the assistant. Pedicle dissection and division is performed as described in the multistep procedure. The dissection can then be taken superiorly until the lesser sac is entered and medial-to-lateral dissection continues as far laterally as possible until the left colon is separated from the retroperitoneum. Lateral detachment can then be performed while the assistant provides medial retraction. This port setup allows much more proximal maneuverability, and with the assistance of the second robotic arm for omental retraction, takedown of the splenic flexure and detachment of the omentum can be completed without repositioning the robotic cart.

For the second part of the procedure, the camera is switched to a 0° scope. The first robotic arm stays in position and remains as the surgeon's right hand and main tool for sharp dissection with either a monopolar scissors or hook electrocautery. The second robotic arm (currently in the right upper quadrant port holding the Maryland grasper) is switched to the left upper quadrant port. The third robotic arm (currently in the left upper quadrant port holding the fenestrated grasper) is repositioned to the left lower quadrant. These two arms, under control of the surgeon's left hand, will be used for retraction of the bladder/vagina/

prostate or rectum as needed (similar to that described in the multistep procedure). This leaves the right upper quadrant is available for use by the assistant to retract the rectosigmoid cephalad, while still having the 5 mm port for suction and/or further retraction. With this setup, the pelvic dissection, division, and specimen extraction can all be performed as previously described.

Robotic rectopexy

PATIENT POSITIONING

The patient should be placed on the operating room table either on a beanbag or with appropriate padding to maintain support in a low lithotomy position. A urinary catheter is placed. The patient is placed in a steep Trendelenburg position, and the robot is docked over the left hip.

PORT PLACEMENT

Four ports are inserted (three robotic and one assistant port). A 12 mm port is placed at the umbilicus for the camera. An 8 mm robotic port is then placed in the right midclavicular line, slightly inferior to the camera port. Another 8 mm robotic port is placed in the left midclavicular line at a horizontal position from the camera port at the level of the umbilicus. A 12 mm port is placed in the right lower quadrant two fingerbreadths cephalad and two fingerbreadths medial off the anterior superior iliac spine. This port will be the assistant's port. These ports should always be separated from each other by at least 10 cm so as to prevent robotic arm collision.

ROBOT POSITIONING

The robot is docked over the left hip, at an angle of approximately 15°–30° to the bed, allowing for the endoscopic arm to dock in a direction parallel to the bed, and looking directly into the pelvis. The first robotic arm attaches to the right lower quadrant 8 mm port and uses a monopolar scissors. The second robotic arm attaches to the left lower quadrant port and uses a bipolar fenestrated grasper.

TECHNIQUE

With the redundant sigmoid reduced from the pelvis and the rectosigmoid retracted cephalad by the assistant, the fenestrated grasper retracts the rectum anteriorly exposing the posterior mesorectal fascia. The avascular plane along Waldeyer fascia, between the rectal fascia propria and presacral parietal fascia, is then dissected sharply with the monopolar scissors all the way inferiorly to coccyx. The posterior plane through the loose areolar tissue between the mesorectum and the presacral plexus of veins is developed. The ureters are lateral to the dissection plane and the inferior hypogastric nerves, and more distally, the pelvic nerve plexus lies posteriorly and should be identified and preserved. Dissection is continued inferiorly and in a medial-to-lateral direction down to the levator ani. Once sufficiently low on the rectum from the inferior and medial plane, left lateral dissection of the lateral attachments of the sigmoid

colon down the rectum along the white line of Toldt can be performed while the rectum is retracted to the right by the assistant. Anterior dissection of the rectum is not required. Once fully mobilized, with the assistant providing recto-sigmoid retraction as cephalad as possible, a needle driver can be placed into the first robotic arm and the mesorectum sutured to the sacral promontory with either a nonabsorbable or V-lock suture using one suture on each side. The lateral peritoneum can then be reapproximated to the peritoneum overlying the rectum, if so desired, with a running suture in an attempt to prevent small bowel returning to the pelvis and resulting in an internal hernia.

ROBOTIC OUTCOMES

Right colectomy

The right colectomy is a less technically demanding procedure than rectal surgery, and while laparoscopic right colectomies have been widely adopted as offering multiple advantages over open surgery as mentioned earlier, robotic right colectomies have not yet found their footing in the field. There are only a few studies comparing laparoscopic versus robotic right colectomy. These tend to be single-institution retrospective reviews with small sample sizes. One meta-analysis¹³ that included six such studies (only one was a randomized control trial) performed between 2009 and 2013 at well-known institutions with significant levels of experience in both laparoscopic and robotic colon and rectal surgery demonstrated no significant difference in terms of perioperative outcomes between the two groups. It was noted, however, that the robotic group tended to have younger patients with lower ASA scores, demonstrating a selection bias favoring the robotic group. However, with regard to short-term results such as operative outcomes (estimated blood loss, conversion to hand-assisted or open surgery), postoperative outcomes (intra-abdominal infection, wound infection, and development of anastomotic leak), postoperative length of stay, rates of reoperation, and overall mortality, the outcomes were comparable. There was noted to be a significant trend toward longer operative times in the robotic group ($p = 0.0004$). Oncologic outcomes were not calculated as the studies focused more on short-term outcomes, and long-term survival data were not reported. However, number of lymph nodes retrieved (often used as a measurable factor of oncologic resection) was similar between the two groups. Only two studies within the meta-analysis mentioned cost, and though not statistically significant, it was observed that the robotic group did appear more costly ($p = 0.0693$).

Left colon/sigmoid/rectum

ESTIMATED BLOOD LOSS

The majority of studies demonstrate either equivalent or less intraoperative blood loss for the robotic technique versus

laparoscopic. This may be due to the increased visualization allowed with the robot, as well as the improved dexterity and precision of motion to aid in vascular and mesenteric dissection.

OPERATIVE TIME

The majority of studies suggest that operative time for robotic surgery is longer than that for laparoscopic procedures. However, there are mixed data to suggest whether it is statistically significant. Using a new platform and instruments that lack haptic feedback likely contribute to this prolonged operative time. Likewise, the key component often cited as the main culprit for this delay is the process involving setup and docking of the robot. With increasing experience and overcoming the learning curve, on the part of both surgeon and operative room staff, these times can be significantly reduced.

CONVERSION RATE

A conversion rate to open or hand-assisted surgery for conventional laparoscopic colon and rectal procedures has been identified to be 29% in the CLASSIC trial (a multicenter, randomized control trial), most of which has been attributed to the effect of the learning curve for laparoscopic surgery. This was made evident by the yearly reduction in conversion rate through the study. However, even in the subsequent COLORII trial that involved more experienced surgeons, the conversion rate was still 17%. This is compared to the data for robotic rectal procedures that one systematic review identified to range from 1% to 7.3%, demonstrating that the robotic approach may lower conversion rates for colon and rectal procedures. Moreover, another study that also demonstrated a significant reduction in conversion rates for robotic procedures (19% versus 0%) interestingly noted that the robotic group had a higher number of patients who underwent neoadjuvant chemoradiation therapy and that the majority of patients in the robotic group had previous abdominal surgery and also had distal rectal cancer requiring complete TME. This suggests that robotic rectal surgery may be better for these more conventionally difficult patients.

ANASTOMOTIC LEAKAGE

Anastomotic leakage is one of the most feared complications following colon and rectal surgery, and the rate has been shown to be increased in patients with lower rectal cancer, as well as obese patients, especially if they received chemoradiation therapy prior to surgery. However, data from three comparative studies suggest a lower rate of anastomotic leakage in robotic rectal surgery, though not statistically significant. Conversely, in another individual study, Baek et al. reported a higher leakage rate of 8.6% for robotic surgery versus 2.9% for conventional laparoscopy, though also not statistically significant ($p = 0.62$). One systematic review performed, that included 18 studies comprising 11 case series and 7 comparative studies assessing robotic versus laparoscopic surgery for rectal cancer, identified a

median anastomotic leakage of 7.6% (range, 1.8%–13.5%) for robotic procedures versus a median anastomotic leakage of 7.3% (range, 2.4%–11.2%) for standard laparoscopic procedures. These data demonstrate that at the very least there is no increased rate of anastomotic leakage with robotic colon and rectal surgery.

POSTOPERATIVE LENGTH OF STAY

When used in conjunction with a fast track approach to postoperative care, robotic surgery has been found to be either comparable or better than the laparoscopic equivalent in the majority of studies. This reduction in hospital stay can serve to improve patient outcomes, ability to return to work, and overall cost effectiveness.

ONCOLOGICAL DATA

Though long-term survival data for robotic versus laparoscopic procedures are lacking, substitute oncologic data such as positive margin rate and number of lymph nodes retrieved have not been shown to be significantly different across multiple comparative studies.

AUTONOMIC NERVE PRESERVATION

An important part of rectal cancer surgery and performing a total mesorectal excision is preservation of the autonomic nerves controlling bladder and sexual function. Data from the CLASSIC trial have indicated that patients undergoing laparoscopic rectal surgery have worse autonomic nervous function postoperatively, possibly due to improper dissection of Denonvilliers fascia and injury to the lateral neurovascular bundles. The precision allowed with the robot in performing this task has demonstrated, in more than one study, a return to baseline in both urinary and sexual function in half the time compared to laparoscopic TME.

Urinary retention

There have been a few studies that identified almost equivalent median rates of 2.6% versus 2.4% for urinary retention in robotic versus laparoscopic procedures. However, there have been a few other studies that failed to identify any urinary dysfunction in the robotic group.

Sexual dysfunction

This has not been well studied in the literature. However, one study did identify reported rates of 5.5% versus 16.6% for robotic versus laparoscopic rectal procedures, but without statistical significance.

Fecal incontinence

This also has not been well studied, but the same study noted previously demonstrated rates of 6.8% versus 2.7% incidence of fecal incontinence for robotic versus laparoscopic rectal procedures, also without statistical significance.

CONCLUSION

Over the almost two decades since its first use, there has been slow, but continuing adoption of robotics within colorectal surgery. The promises of robotic procedures, such as improved visualization, dexterity, and ergonomics, along with a potentially shorter learning curve than minimally invasive surgery, have started to provide a hint of benefits in outcomes, including less blood loss and fewer conversions to open procedures. Yet, at this point, there has not been substantive improvement in the critical complication of anastomotic leak nor a benefit in oncological outcomes.

For greater adoption of robotics to occur, some disadvantages must be overcome, namely, training, longer operative time and, perhaps most importantly, higher cost. With the impending addition of new commercial robotic ventures to the field, it is anticipated that technological advances will occur at an accelerating pace. Faster and easier docking could substantially decrease operative time, while advances in haptic technology may provide surgeons with a surgical experience superior to that of direct instrumental contact. More competition will also drive down the cost structure, allowing wider dissemination of robotics globally.

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Hand-assisted colectomy techniques

PETER W. MARCELLO

INTRODUCTION

Hand-assisted laparoscopic surgery (HALS) is a hybrid laparoscopic approach by which the surgeon inserts a hand inside the abdomen to facilitate the laparoscopic dissection. Pneumoperitoneum is maintained using a commercial device that seals off the abdominal cavity from the surrounding environment but allows insertion or withdrawal of a hand or instrument at will. Laparoscopic colorectal surgery lends itself particularly well to HALS, because an incision is often required for specimen retrieval, whether it is done at the beginning or at the end of the procedure. The potential advantages of HALS include the restoration of tactile feedback and proprioception, the ability to perform blunt dissection, the ability to retract organs atraumatically, the ability to apply immediate hemostasis with the surgeon's hand, a potential reduction in the number of ports required to perform the resection, and improved surgeon comfort level while performing the dissection. In the context of malignancy, tumor palpation may be another invaluable clinical advantage. For complex cases or inflammatory conditions, the hand and fingers are useful tools to safely perform blunt dissection of inflamed tissue. A meta-analysis of the three published randomized control trials comparing hand-assisted laparoscopic to conventional laparoscopic colorectal resection showed a significantly lower rate of conversion in the hand-assist patients, while morbidity rates were equivalent. The meta-analysis further indicated that short-term postoperative benefits of conventional laparoscopic colectomies were preserved, and costs were likely to be offset by reduced operative time and specific need of laparoscopic equipment. Simply put, the major goal of HALS is to restore the operative ease of open surgery while preserving the technical and short- and intermediate-term benefits of standard laparoscopy.

INDICATIONS/CONTRAINDICATIONS

A hand-assisted approach compared to a straight laparoscopic approach has been associated with a reduction in operative time and fewer conversions. Therefore, this is the author's preferred approach for several main categories of procedures, diseases, and patients.

Indications

- Inflammatory conditions—diverticulitis, inflammatory bowel disease. The hand and fingers can allow for safe blunt dissection. When bleeding occurs with dissection, it is very easy to use a gauze through the hand device to tamponade and control inflammatory bleeding.
- Complex procedures—total colectomy, proctocolectomy, extended left colectomy with Turnbull technique (transverse colon through ileal mesentery).
- Complex patients: morbidly obese patients—this is a significant percentage of patients. When a patient with body mass index (BMI) greater than 30 requires a colorectal resection, the hand can be an extremely useful tool with minimal (<2 cm) difference in the size for the extraction incision—typically 8 cm for HALS and 6–6.5 cm for straight laparoscopic resection. This is also useful for patients with a moderate volume of intra-abdominal adhesions, either inflammatory or from prior surgery.

Contraindications

- Extensive adhesion formation from prior surgery
- Inability to tolerate pneumoperitoneum

PREOPERATIVE PLANNING

There is no specific preoperative planning needed for a laparoscopic approach compared to conventional open surgery. Appropriate preoperative antibiotics, heparin administration, and marking of a site for temporary fecal diversion should be planned.

SURGERY

Positioning

The patient is placed in a modified lithotomy position on a split-leg electric table.

- The arms are at the sides and surrounded by a beanbag.
- Three-inch silk tape is wrapped around the patient and beanbag to the table.

Technique

The operation begins with creating an incision for the planned extraction with insertion of the hand device (**Figure 92.1**). For left colectomy and total colectomy or proctocolectomy, a Pfannenstiel incision is the preferred technique of access. Early in the learning curve of HALS,

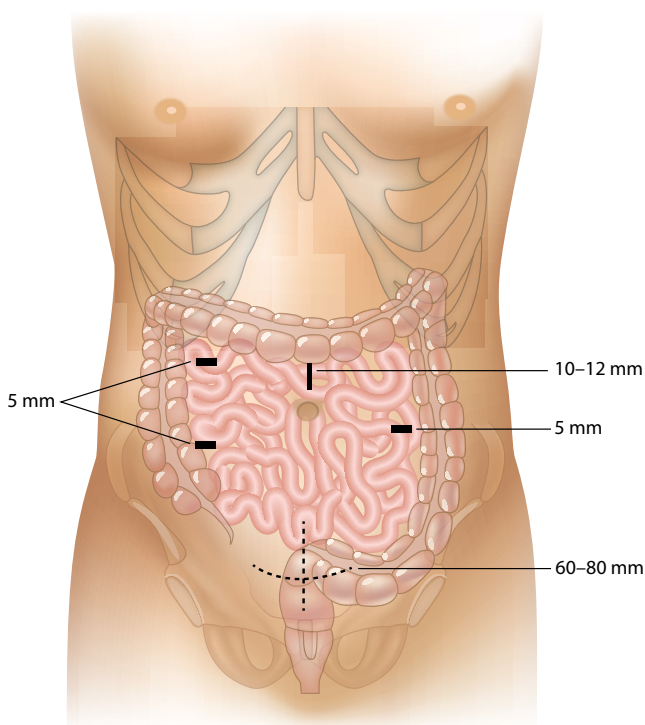


Figure 92.1 Port placement. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

an 8 cm lower midline incision (two fingerbreadths above the pubic symphysis) is recommended in case conversion is required. Once the surgeon is comfortable with a hand-assist approach, a Pfannenstiel is the preferred approach. The incision is cosmetically pleasing, has an extremely low risk of incisional hernia, and is an excellent incision in the pelvis to work in, where further dissection or an anastomosis can be completed.

An 8 cm Pfannenstiel incision is made two fingerbreadths above the pubic symphysis:

- The anterior rectus sheath is incised transversely and superior, and inferior flaps are created over the rectus muscles.
- The peritoneum is opened vertically between the rectus muscles.
- The sleeve for the hand device is placed.
- Then 5 mm trocars are positioned in the left lateral, umbilical, and right lateral positions. Trocars are placed with the hand inside the abdomen to protect the intestine from injury. An additional 5 mm port may be placed in the right upper quadrant if an initial diagnostic laparoscopy is needed before committing to a HAL procedure (**Figure 92.1**).

RIGHT COLECTOMY: MEDIAL APPROACH

For a total colectomy, the procedure begins with devascularization and mobilization of the right and transverse colon. Then an extended left colectomy completes the mobilization of the colon, which is then extracted through the hand device.

To begin the procedure, the surgeon stands on the patient's left side with the left hand through the hand port and the right hand with a laparoscopic instrument (**Figure 92.2**). The assistant stands cephalad to the surgeon, holding the camera. The patient is in slight Trendelenburg position with the right side up.

- An exploration is undertaken. The colon is examined to determine the extent and severity of disease. The small bowel is examined to exclude Crohn disease if indicated.
- The cecum and terminal ileum are elevated and retracted laterally with the hand.
- A medial-to-lateral dissection of the right and transverse mesocolon is performed. An incision is made under the ileocolic pedicle, and the duodenum is swept downward (**Figure 92.3**). The ileocolic pedicle is then isolated. The fingers are quite useful for isolating the pedicles. The ileocolic vessels are then divided and ligated using a bipolar vessel sealing device (**Figure 92.4**). The 5 mm bipolar sealing device is the preferred method of vessel ligation and division. Multiple applications of the device are used before the pedicle is divided. Although somewhat controversial, the ileocolic vessels are divided when performing a proctocolectomy and ileoanal pouch construction.
- The right-sided colon is mobilized from medial to lateral (**Figure 92.5**). The colon mesentery is freed from the

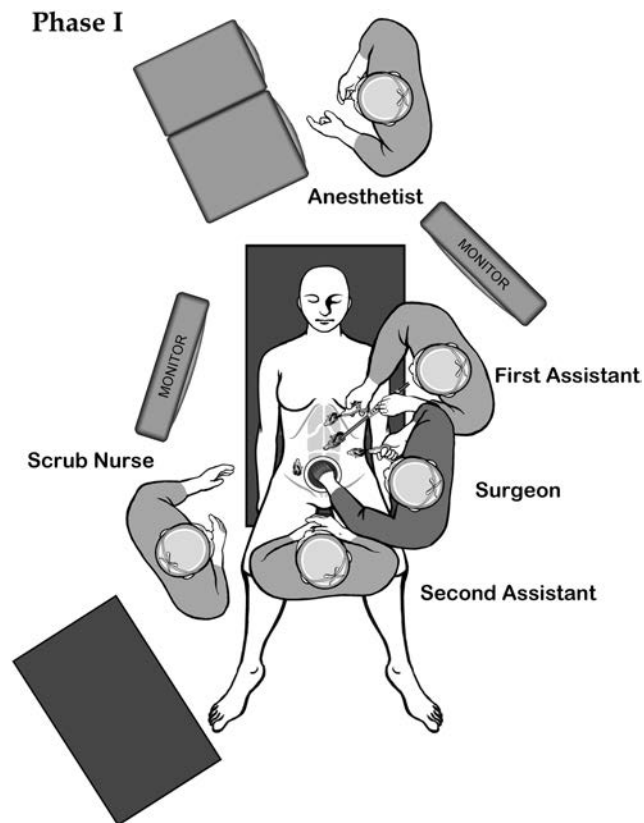


Figure 92.2 Right colectomy—medial approach. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

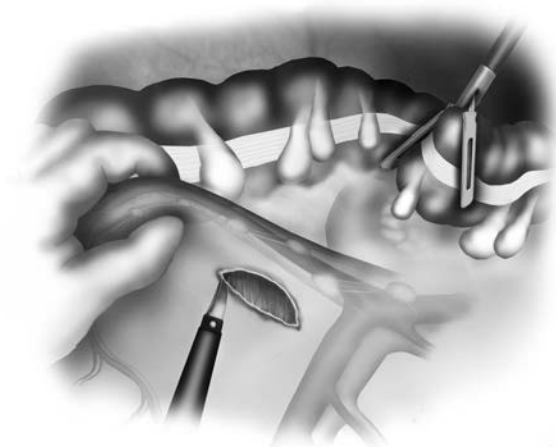


Figure 92.3 An incision is made under the ileocolic pedicle, and the duodenum is swept downward. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)



Figure 92.4 The ileocolic vessels are then divided and ligated using a bipolar vessel sealing device. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

retroperitoneum and duodenum. A hand is used to create traction, while the scissors are used to perform the dissection.

- If present, the right colic vessels are now isolated and divided.

TRANSVERSE COLECTOMY: MEDIAL APPROACH

Attention is then shifted to the transverse mesocolon. The assistant moves from the patient's left side to stand between the legs. The assistant's left hand elevates the transverse mesocolon with a laparoscopic instrument through the right lateral trocar. The assistant's right hand controls the camera through the umbilical port. The surgeon remains on the patient's left side with the left hand through the hand device and the right

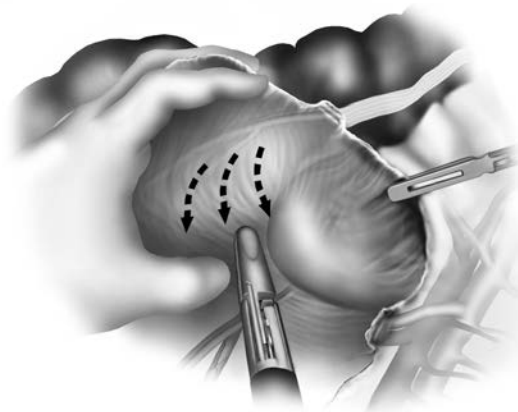


Figure 92.5 The right-sided colon is mobilized from medial to lateral. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)



Figure 92.6 The dissection generally begins to the left of the midline in the transverse mesocolon. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

hand with a laparoscopic instrument. The assistant elevates the transverse mesocolon with a grasper in the left hand through the right-sided trocar, while the surgeon isolates each of the individual middle colic vessels. The dissection generally begins to the left of the midline in the transverse mesocolon (**Figure 92.6**). This plane often has fewer adhesions into the lesser sac. The lesser sac is entered and the distal transverse mesocolon sharply divided. Each of the middle colic vessels is isolated and then ligated with the bipolar vessel sealer.

Working back toward the patient's right side, the right-sided branches are isolated and divided (**Figure 92.7**). The

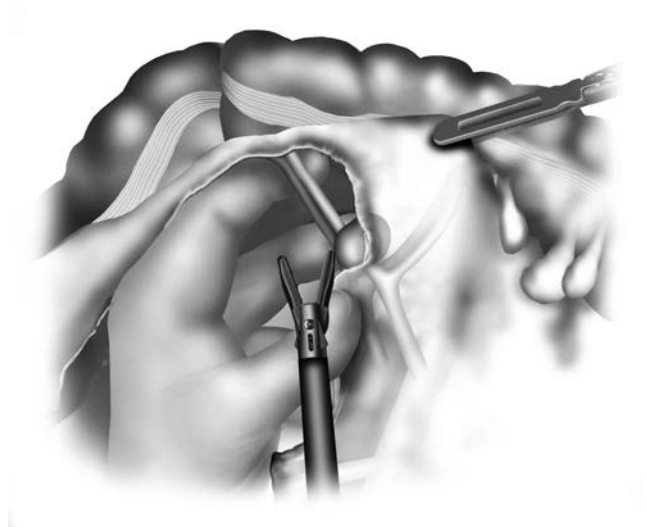


Figure 92.7 Working back toward the patient's right side, the right-sided branches are isolated and divided. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

middle colic vessels may sometimes be ligated together or individually. In the setting of colon cancer, then high pedicle ligation can be achieved, and typically the separate branches of the middle colic artery are isolated rather than the shortened main trunk of the middle colic artery. Excessive tension on the vessels should be avoided when using a bipolar vessel-sealing device. The smaller venous branches may tear if there is excessive tension. The entire proximal and mid-transverse mesocolon has now been fully divided.

RIGHT AND TRANSVERSE COLECTOMY: LATERAL APPROACH

The terminal ileum and right colon are now mobilized laterally. This portion begins by straight laparoscopic technique.

- Scissors are placed directly through the hand device, and a grasper through the left lateral trocar. The cecum and terminal ileum are mobilized.
- The hand is then used to help mobilize the terminal ileal mesentery up to and then over the duodenum. This is a critical lengthening maneuver when performing ileoanal pouch construction.
- The remaining lateral attachments are divided with the assistant using the hook cautery through the right lateral trocar, and the surgeon remaining in the same position with the left hand in and the right hand with a laparoscopic grasper.
- The bipolar vessel sealer may also be used to help separate the omentum and control any minor bleeding (**Figure 92.8**). If the planes are well established, then a monopolar hook cautery is preferred. The assistant remains between the legs again with the hook in his or her left hand (coming through the right-sided trocar) and the right hand on the camera. The surgeon uses the left hand to grasp the colon and a grasper in the right hand to apply the tension. The surgeon maintains control of the dissection by keeping the electrocautery foot pedal to only allow the hook to dissect when there is appropriate traction and countertraction.
- With the right and transverse colon mobilized and devascularized, it is placed back into anatomical position before turning to the left colectomy.

LEFT COLECTOMY

The surgeon now stands on the patient's right side with the right hand through the hand device and the left hand with an instrument through the right lateral trocar site. The assistant stands cephalad to the surgeon, holding the camera (**Figure 92.9**). The patient is in a mild Trendelenburg and left-side up position. The small bowel is packed out of the pelvis to the right upper quadrant with a sponge that is brought through the hand device.

If the indication for surgical resection includes cancer of the left colon or rectum, then a dissection that will include the inferior mesenteric artery (IMA) pedicle will follow. There is the potential risk of injury to the hypogastric nerves when performing a high pedicle ligation.

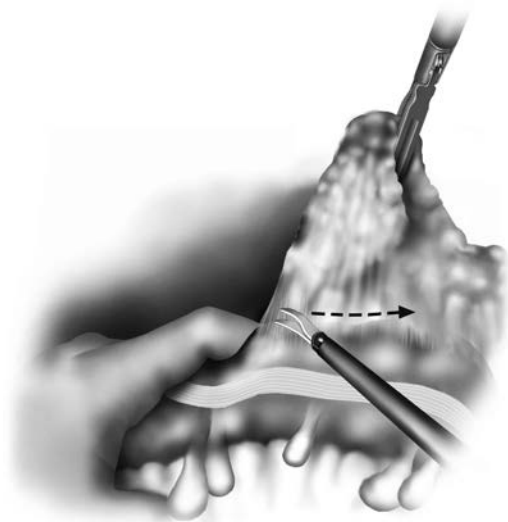


Figure 92.8 The bipolar vessel sealer may also be used to help separate the omentum, and control any minor bleeding. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

Phase II

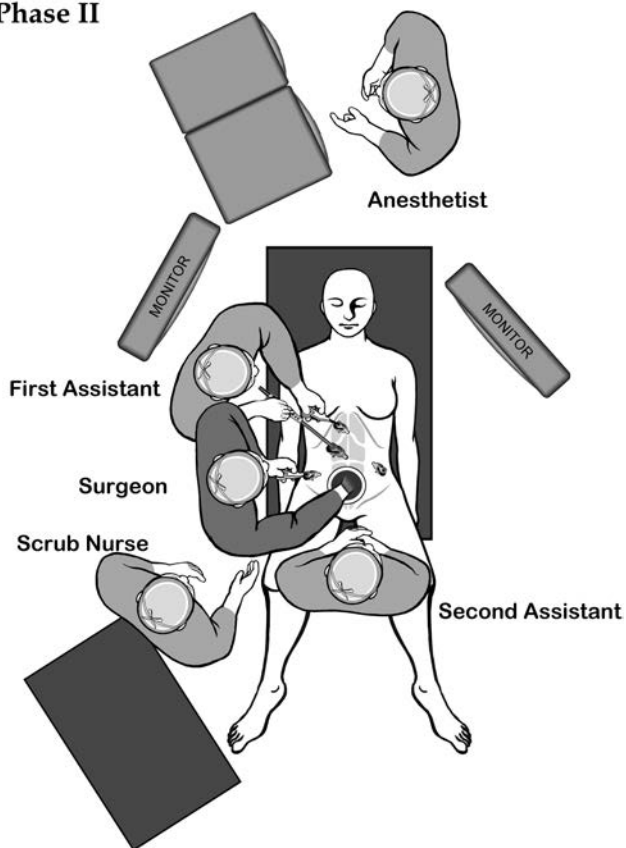


Figure 92.9 Left colectomy. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

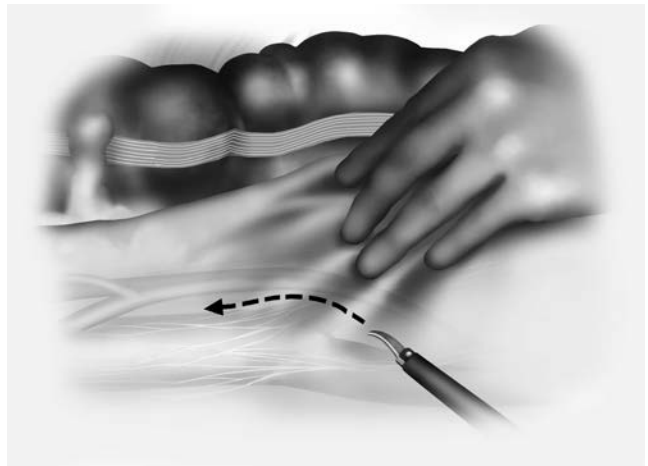


Figure 92.10 The right hand elevates the IMA pedicle, and an incision is made along the right peritoneal fold of the rectosigmoid mesentery extending into the pelvis. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

- The right hand elevates the IMA pedicle, and an incision is made along the right peritoneal fold of the rectosigmoid mesentery extending into the pelvis (Figure 92.10). The plane beneath the inferior mesenteric pedicle is a developed heading to the left side. Care is taken to sweep down the sympathetic nerve fibers of the hypogastric nerves (Figure 92.11). A plane is developed over the left ureter and left gonadal vessels, and the IMA pedicle is

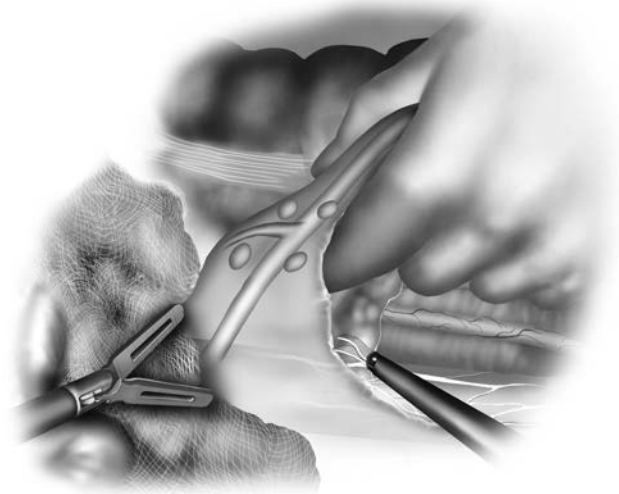


Figure 92.11 Care is taken to sweep down the sympathetic nerve fibers of the hypogastric nerves. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

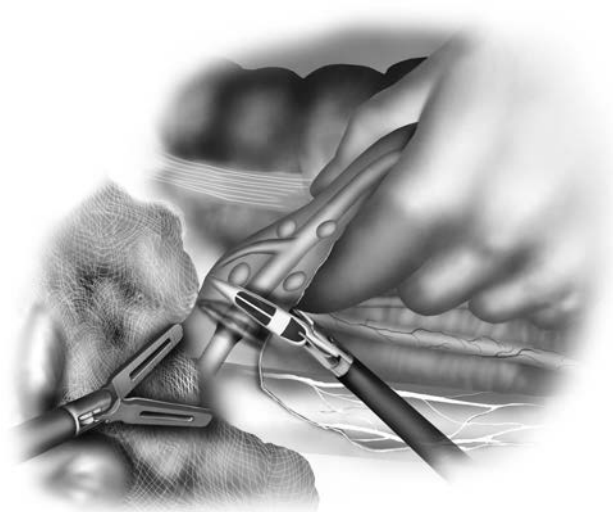


Figure 92.12 A plane is developed over the left ureter and left gonadal vessels, and the IMA pedicle is isolated and divided below or above the takeoff of the left colic vessels depending on the location of the lesion and surgeon preference. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

isolated and divided below or above the takeoff of the left colic vessels depending on the location of the lesion and surgeon preference (**Figure 92.12**).

If the indication for resection does not include the risk of carcinoma, then the preference is to preserve the IMA and superior hemorrhoidal pedicles into the pelvis to reduce the risk of injury to the hypogastric nerves. In this setting, the right hand elevates the mesentery lateral to the inferior mesenteric vein in the “bare area” of the left colon between the left colic vessels and the first sigmoidal branches. The mesentery is incised just lateral to the inferior mesenteric vein, and a dissection begins between the left colon mesentery and Gerota fascia. The gonadal vessels will be below with Gerota fascia, and the dissection continues out to the lateral side wall. The ureter is typically under the IMA pedicle and will not be seen. The sigmoid branches are identified, isolated, and divided with bipolar vessel sealer.

- The next step for both techniques involves mobilization of the left colon from medial to lateral in a plane overlying Gerota fascia (**Figure 92.13**). This dissection will continue out to the left pelvic sidewall, inferiorly, into the upper retrorectal space, and superiorly, we will come up and under the mesentery toward the splenic flexure.
- The left colon mesentery is divided medially, and the left colic vessels are isolated and divided as indicated. For total colectomy, all vessels are taken. For a left-sided resection, then whether the left colic vessels are divided

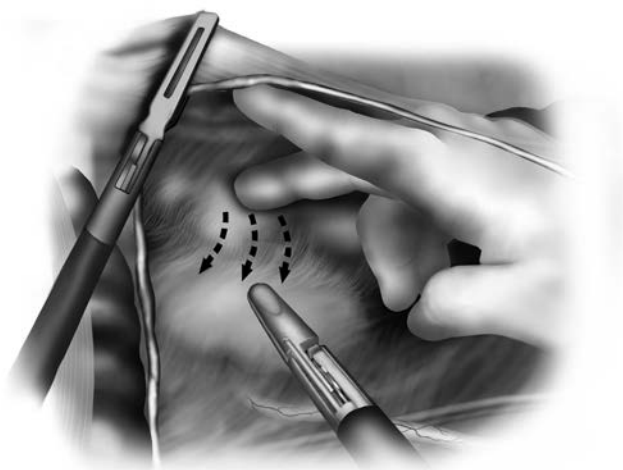


Figure 92.13 The next step for both techniques involves mobilization of the left colon from medial to lateral in a plane overlying Gerota fascia. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

is dependent on the indication for surgery and surgeon preference. The medial dissection continues out to the lateral sidewall where the line of Toldt can be divided.

- The lateral attachments may now be divided. The white line of Toldt is divided through the left lateral trocar (**Figure 92.14**).
- The splenic flexure and remaining transverse mesocolon are now divided. The assistant stands between the legs, holding the camera with the left hand and the hook cautery with the right hand through the left-sided trocar (**Figure 92.15**). This is similar to the approach that was

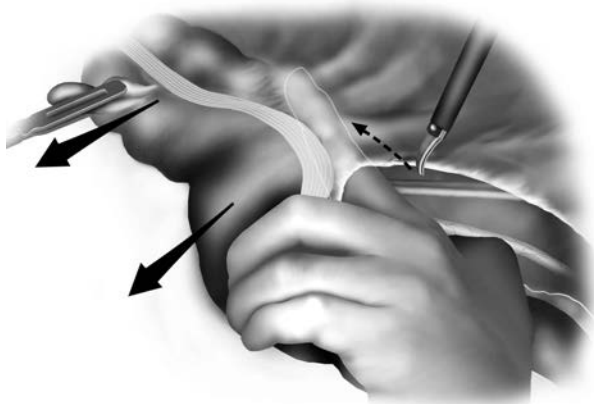


Figure 92.14 The lateral attachments may now be divided. The white line of Toldt is divided through the left lateral trocar. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

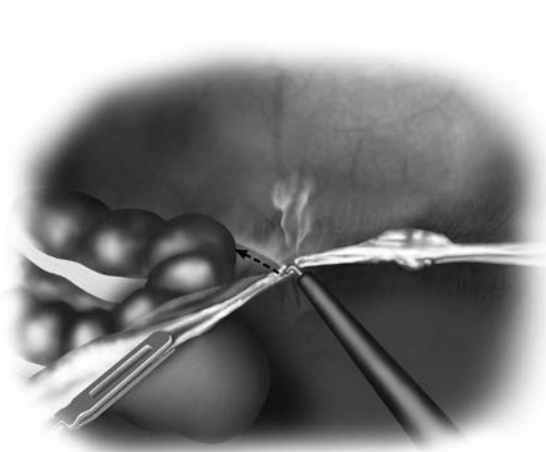


Figure 92.15 The splenic flexure and remaining transverse mesocolon are now divided. The assistant stands between the legs, holding the camera with the left hand and the hook cautery with the right hand through the left-sided trocar. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

used to separate the omentum from the proximal transverse colon. The left-sided attachments of the omentum to the distal transverse colon are divided (**Figures 92.16 and 92.17**). Then the distal transverse mesocolon is freed from the inferior boarder of the pancreas. For a left-sided resection, the colon is now fully mobilized, and the specimen is extracted through the hand port. The proximal transection, distal transection, and anastomosis are then completed through the extraction site. This greatly reduces the time of the procedure. If a stapled colorectal anastomosis is planned, then before the circular stapler is fired,

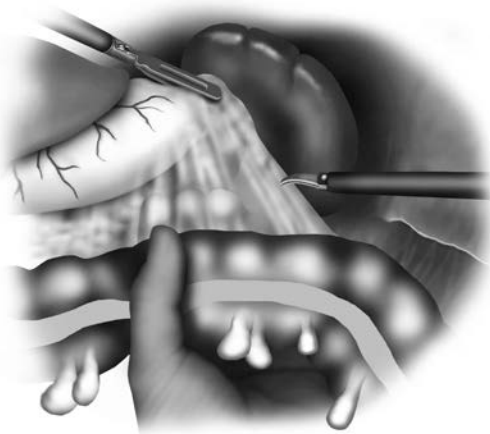


Figure 92.16 The left-sided attachments of the omentum to the distal transverse colon are divided. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

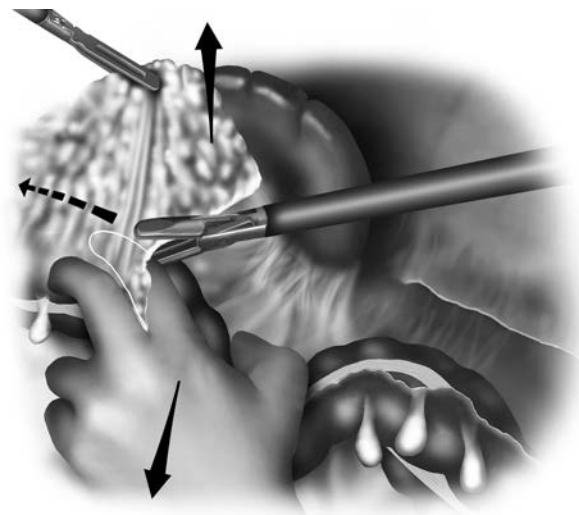


Figure 92.17 The left-sided attachments of the omentum to the distal transverse colon are divided. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

a pneumoperitoneum is recreated to ensure the proximal colon and its mesentery are not twisted and that the small bowel is not trapped under the left colon mesentery.

- For a total colectomy or proctocolectomy, following omentum separation, the remaining portion of the distal transverse mesocolon is divided. Here, the assistant elevates the mesentery with a grasper, and the surgeon divides the mesentery with a bipolar sealer, using the left hand through the right-sided trocar.
- With the entire mesocolon now divided, the retroperitoneum and major pedicles are examined with a sponge to ensure excellent hemostasis. The table is tilted into a Trendelenburg position with the right side up, allowing all of the small intestine to shift to the left upper quadrant. The colon is brought over the small intestine, beginning at the splenic flexure, to the right lower quadrant (**Figure 92.18**). The terminal ileal mesentery can be followed up to, and then over the duodenum, with the entire small bowel to the left of midline (**Figure 92.19**). This step is critical to ensure proper orientation of the small bowel mesentery if an ileorectal anastomosis or ileoanal pouch construction is planned. This step should be performed before moving on to the mobilization of the rectum.

Extraction, anastomosis, and closure

For a proctocolectomy, the rectal mobilization can be done in a hand-assisted approach, a straight laparoscopic approach, or by an open technique through the Pfannenstiel incision, depending on the surgeon's preference, the surgeon's skill

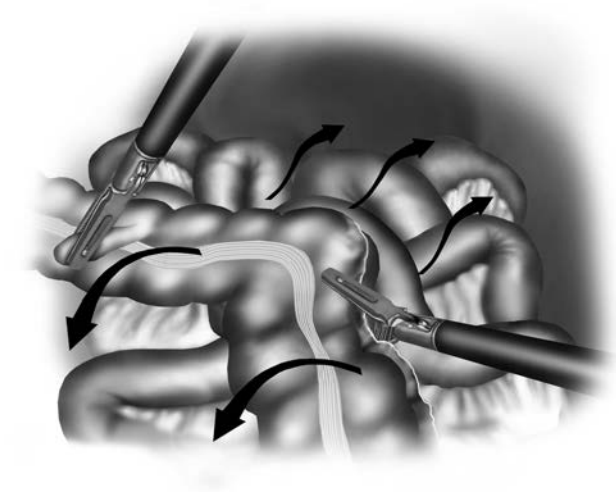


Figure 92.18 The colon is brought over the small intestine, beginning at the splenic flexure, to the right lower quadrant. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

with laparoscopic proctectomy, and specific patient characteristics as they relate to the pelvic anatomy.

The colon and terminal ileum are delivered through the wound (Figure 92.20). For a total colectomy, through the open wound, one should follow the terminal ileal mesentery up to and over the duodenum, confirming proper orientation. The terminal ileal mesentery is divided between



Figure 92.19 The terminal ileal mesentery can be followed up to, and then over the duodenum, with the entire small bowel to the left of midline. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

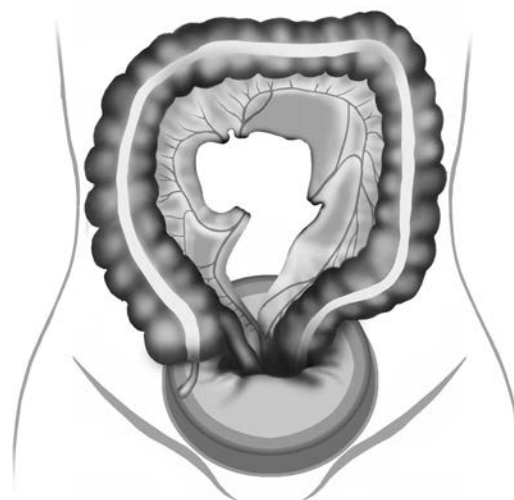


Figure 92.20 The colon and terminal ileum are delivered through the wound. (With kind permission from Springer Science+Business Media: *Laparoscopic Colorectal Surgery*, 2006, Milsom J et al. [eds.], 2nd ed., New York, NY: Springer-Verlag.)

clamps and ligated. The remainder of the procedure is performed using the extraction site.

The peritoneum of the Pfannenstiel incision is closed vertically. The rectus muscle is reapproximated loosely with interrupted sutures. The anterior rectus sheath is closed transversely. The incisions are closed with absorbable suture. The wounds are covered, and the ileostomy is matured.

POSTOPERATIVE MANAGEMENT

The patient is on a standardized accelerated postoperative care plan. Diet is slowly advanced, the patient is transitioned to oral analgesics, and the Foley catheter is removed on postoperative day 1–3 depending on the procedural details and postoperative recovery. Appropriate education of ileostomy care is initiated before, during, and after hospitalization. A water-soluble enema and flexible endoscopy are performed 6 weeks postoperatively, and plans are made for ileostomy closure approximately 8 weeks following the original procedure.

COMPLICATIONS

Numerous complications can occur following restorative proctocolectomy whether performed laparoscopically or by open technique. The only complication that is unique to a hand-assisted technique compared to conventional open surgery is the risk of small bowel obstruction at the level of the ileostomy as previously described. Creation of the ileostomy aperture through the anterior rectus sheath before

creation of the Pfannenstiel incision has greatly reduced the risk of this complication.

RESULTS

Extensive colorectal resections and reconstructions, including total abdominal colectomy and total proctocolectomy with ileal pouch-anal anastomosis (IPAA), are undoubtedly among the most technically challenging operations to perform laparoscopically. Hand-assisted techniques prove to be particularly relevant in allowing the adoption of minimally invasive total colorectal resections by a wider group of surgeons.

Rivadeneira and colleagues reported 23 prospectively collected cases of restorative proctocolectomy performed using hand-assisted or straight laparoscopy. The authors found that HALS was associated with shorter operative times (247 versus 300 minutes, $p < 0.01$), but with otherwise comparable postoperative variables. A similar retrospective review of 23 patients by Nakajima et al. reported comparable results, including a shorter operative time of 63 minutes favoring the HALS group. Both case series represent early experiences with HALS total colorectal resections, and, as such, were likely underpowered.

Boushey and colleagues have published the largest such prospective database series to date, in which they compared two groups of patients undergoing HALS ($n = 45$) or straight laparoscopic ($n = 85$) total abdominal colectomy and total proctocolectomy. Again, the authors found a trend toward reduced operative times, in addition to significantly decreased conversion rates favoring the HALS group (2.2% versus 7.1%, $p < 0.01$). As with segmental resections, this group also demonstrated that nonlaparoscopic colorectal staff surgeons performed a much larger proportion of cases using the hand-assisted technique compared to a straight laparoscopic procedure (20% versus 4.7%, $p = 0.02$).

As part of their multicenter randomized control trials comparing HALS to straight laparoscopy, Marcello and colleagues published data pertaining to total colectomies

and total proctocolectomies. Although reporting on a small number of patients ($n = 29$), this portion of the trial did demonstrate a significant decrease in skin-to-skin operative time associated with HALS of almost 1.5 hours (199 versus 285 minutes, $p = 0.015$). This difference was also evident when the time to colectomy completion was analyzed (127 versus 184, $p = 0.015$). Despite this significant time saving, this group did not find any significant difference between the two groups in terms of postoperative recovery.

CONCLUSIONS

Hand-assisted laparoscopic colectomy is the procedure of choice for patients requiring surgery who have complex diagnoses, procedures, or patient factors. In comparison to straight laparoscopic colectomy, HALS is associated with reduced operative time and fewer conversions. In patients who are morbidly obese, the hand is a useful tool for mobilization and dissection of the mesocolon, allowing the complex portions of the procedure to be performed with tactile feel and the anastomosis to be completed through the hand-port site. For surgeons skilled in both laparoscopic and open techniques, this approach allows for reduction in operative time and low rate of conversion while maintaining minimally invasive benefits to the patient.

FURTHER READING

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Minimally invasive therapies for fecal incontinence

ISACCO MONTRONI, CLAIRE E. PEEPLES, AND STEVEN D. WEXNER

INTRODUCTION

Fecal incontinence (FI) is the “recurrent uncontrolled passage of fecal material for at least 1 month,”¹ which effects a considerable part of the population. A 2012 survey among U.S. females showed that approximately 19% of patients aged ≥ 45 years had at least one episode of FI during the preceding 12 months. Despite the fact that approximately 50% reported a severe impact on quality of life,² only 28% sought medical attention, usually from a primary care physician (PCP). Unfortunately, many PCPs may be unaware of the gamut of therapeutic alternatives.

While patients may experience adequate improvement from conservative nonoperative methods, surgery may be indicated. Surgical strategies available for FI are summarized in [Table 93.1](#). This chapter focuses on newer minimally invasive surgical techniques for FI.

Radiofrequency energy delivery (SECCA)

INDICATIONS AND BENEFIT

The first cases of temperature-controlled radiofrequency (RF; SECCA Mederi Therapeutics Inc, Norwalk, Connecticut) treatment for FI were reported in 1999, but it was not until 2002 that data on efficacy were made public after approval by the U.S. Food and Drug Administration (FDA). The American Society of Colon and Rectal Surgeons (ASCRS) guidelines suggest that RF may be an option in patients with mild-to-moderate FI (Cleveland Clinic Florida/Wexner-Fecal Incontinence Score (CCF/Wexner-FIS): 1–14)³ with or without internal anal sphincter defects.⁴ RF therapy can be used after failed sphincteroplasty, or as a last attempt before more invasive surgery.^{4,5}

MECHANISM OF ACTION AND TECHNIQUE

The RF generator is a device designed as an anoscope using transparent material, which allows direct visualization of the anal canal. The device has four nickel-titanium curved needles that deliver energy to each quadrant of the internal anal sphincter (IAS). The device delivers 465 kHz, 2–5 W

from each needle for 60 seconds, and energy to the electrodes is automatically discontinued when the temperature reaches 85°C. The anal mucosa is progressively cooled by constant water irrigation in order to prevent thermal injury.

Hermann et al. used an animal model to demonstrate the effect of RF on the IAS and external anal sphincter (EAS) muscle fibers and analyze the cellularity (number of interstitial cells of Cajal [ICC]) and composition of the connective tissue ([Table 93.2](#)).⁶ These histologic changes provide a new configuration of muscle fibers, collagen, and cells responsible for muscle contraction, the ICC, and can promote increased outlet resistance and possibly improve sensation. Both Takahashi et al.⁷ and Efron et al.⁸ in 2002 and 2003, respectively, were able to show that, as a result of RF, a higher threshold and maximum tolerable balloon volume were obtained.

Table 93.1 Surgical strategy and corresponding surgical repair

Surgical strategy	Surgical option	Minimally invasive
Repair	Sphincteroplasty Postanal repair	
Augmentation		Injectables Radiofrequency
Replacement	Gluteoplasty Graciloplasty (dynamic ^a /adynamic) Artificial bowel sphincter ^a Magnetic anal sphincter ^a	
Stimulation		Sacral nerve stimulation posterior tibial nerve stimulation
Diversion	Standard stoma Malone Antegrade Continence Enema (MACE) procedure	

Source: Wexner SD. *Lancet*. 2015;386(10004):1605–6.⁶⁶

^a Procedures not available in the USA at the time of this publication.

Table 93.2 Effect of radiofrequency on IAS and EAS muscle and connective tissue

IAS	• Increase in smooth muscle content in IAS • Increase in smooth muscle/connective tissue ratio within the IAS • Increase in collagen I/collagen III ratio • Reduction of ICCs network within IAS • Increase of myofibroblasts content within IAS and EAS
EAS	• Increase in diameter and number of type I EAS fibers and fibers I/II ratio

Source: Herman RM et al. *Colorectal Dis* 2014;17. doi:10.1111/codi.12874.

Abbreviations: EAS, external anal sphincter; IAS, internal anal sphincter; ICC, interstitial cells of Cajal.

It is recommended that patients receive two preoperative enemas: one the night before and one on the morning of surgery. The patient can be positioned in the prone or left lateral decubitus position, and conscious sedation with local anesthesia or general anesthesia is advised. The procedure can be performed in the outpatient endoscopy suite or as ambulatory surgery, and the patient is usually discharged the same day of surgery.⁴ Once appropriate anesthesia is obtained, the device is inserted and aligned at the level of the dentate line. The cycle is repeated three or four times at each level (a total of 16 electrode treatments per level), and the device is then advanced cephalad every 5 mm to repeat the four cycles again. A maximum of five levels can be treated; the anoscope is gradually rotated allowing treatment in either three or four quadrants at either 120° or 90° intervals, respectively (**Figure 93.1**).

STRATEGIES TO REDUCE FAILURES AND LONG-TERM RESULTS

Takahashi et al. in 2002⁷ published a pilot series of 10 patients undergoing RF to treat mild-to-moderate FI (CCF/Wexner-FIS between 4 and 17). Eighty percent of the patients had a significant reduction of their CCF/Wexner-FIS of at least 50% on 12-month follow-up. In addition, there was significant improvement in the FI Quality of Life (FIQL) Index⁶⁷ with reportedly improved lifestyle, coping, depression, and embarrassment scores.

In order to ensure optimal success with RF treatment, one needs to ensure that the patient still has a significant amount of sphincter due to the action on smooth and striated muscle fibers. Previous studies have demonstrated poor results in patients with a significant preoperative sphincter defect (>30%) who underwent RF.⁹ In addition, concomitant perianal disease such as anal fistula or fissure is an absolute contraindication, and a prior rectovaginal fistula is considered as a relative contraindication to RF.⁴

Table 93.3 summarizes the most relevant studies reporting mid- and long-term outcomes. Several studies have reported statistical significance when comparing pre- and postoperative CCF/Wexner-FIS.^{5,10,11} Despite this outcome, however, all studies did show a significant improvement in quality of life.^{12–16}

A few minor postoperative complications have been reported (**Table 93.3**) and are usually limited to postoperative

pain, hematoma/bleeding, and mucosal ulceration. In all cases, conservative management has been advocated with no reported associated long-term disability.

No case series has been published regarding redo-RF after the first attempt. Efron et al.⁸ described 11 patients who had previously undergone surgery for FI, 9 had primary sphincteroplasty while 2 had previous artificial bowel sphincter (ABS) placement with poor results. No functional data are reported in that publication, however.

Overall, RF can be used as part of the armamentarium in the treatment of FI, and may be utilized as either a bridge or as a definitive therapy. A part of the appeal of RF is the standardization of the procedure and the fact that the tissue remodeling continues to improve over time.

Injectable bulking agents

INDICATIONS AND SHORT-TERM OUTCOMES

Originally described as a treatment for urinary incontinence, injection of bulking agents to treat “partial” FI was first reported in 1993 in Egypt by the late Ahmed Shafik, who injected autologous fat into the submucosal space of the distal rectum/anal canal.^{17,18} Since that initial description, there have been numerous bulking agents that have been studied and trialed in order to find the ideal “injectable”—nonbiodegradable, biologically nonreactive, nonmigratory, and easy to inject (**Tables 93.4 and 93.5**).^{18,19,21–31}

At the time of this writing, dextranomer in stabilized hyaluronate acid, or NASHA Dx (Solesta; Salix Pharmaceutical Inc, Raleigh, North Carolina) is the only bulking agent that is FDA approved. Graf et al. identified 278 patients, 136 of whom received NASHA Dx and 70 received sham treatment and were then followed up for 12 months.³⁰ The authors were able to show a significant difference between the groups, with a reduction in the number of FI episodes by ≥50% in the study group. Of note, while 52% of the patients in the treatment group reported substantial benefit, 31% in the sham group had comparable effects. Results also showed that NASHA-Dx injection was associated with an increased number of incontinence-free days and a decreased number of incontinence episodes at 6 months.

Similar to RF, bulking agents can be considered as a viable approach prior to more invasive surgery in patients with mild-to-moderate FI.⁴ It is important to note that the ASCRS guidelines discourage the use of bulking agents within 1 year from any prior anorectal surgery.⁴

TECHNICAL TIPS TO REDUCE FAILURE, MID- AND LONG-TERM RESULTS

Several techniques and strategies have been described when using “injectables” in the sphincter region for FI, in order to optimize results. In a systematic review by Hussain et al., sites of implantation and routes of injection are summarized (**Figure 93.2**).³² The authors aimed to exclude any possible association between the type of molecule, route and site of injection, use of ultrasound as a guide, pre- and

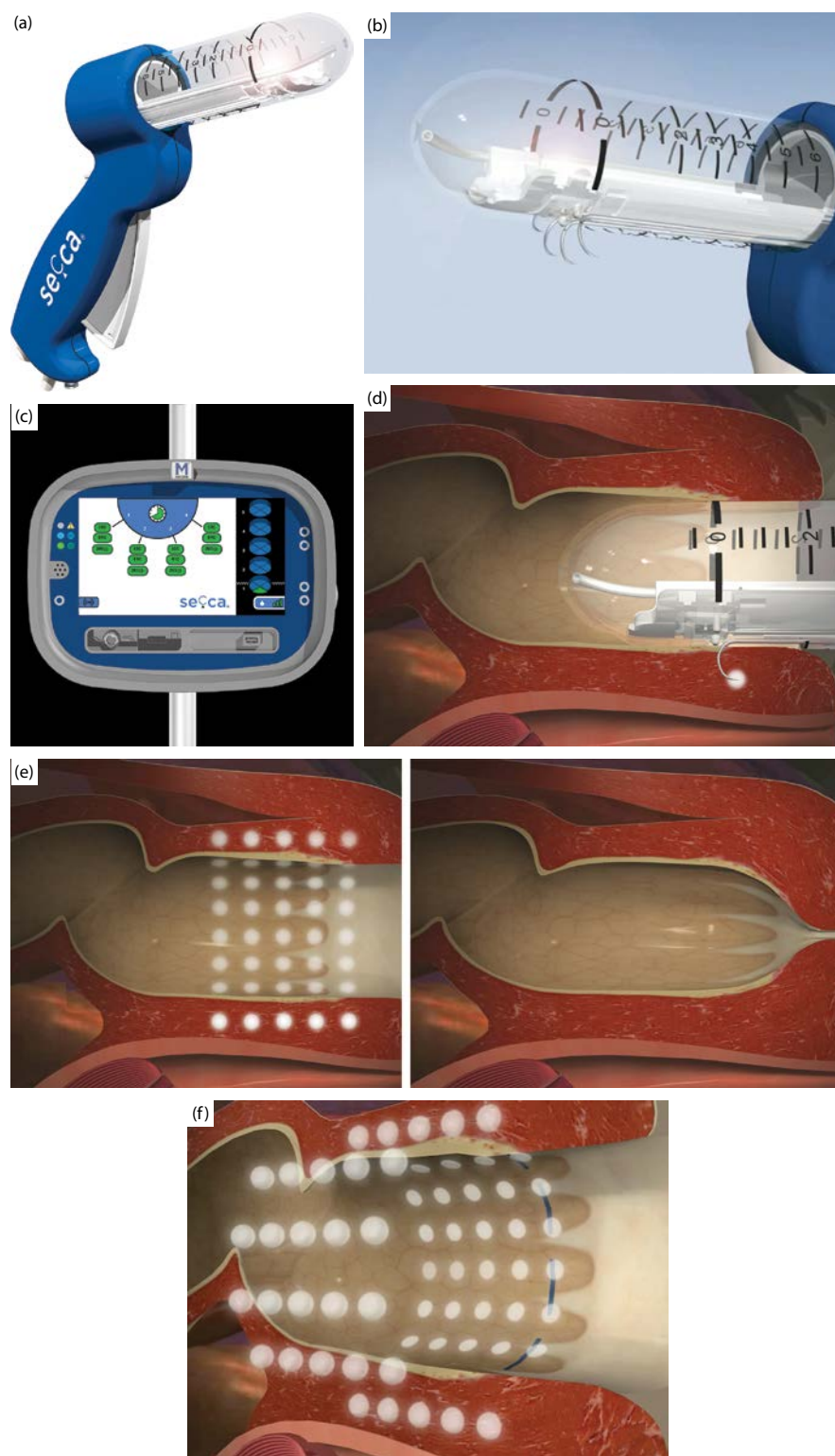


Figure 93.1 Radiofrequency energy delivery (SECCA). (a) The radiofrequency (RF) generator, designed as a transparent anoscope to allow direct visualization of the anal canal. (b) Four nickel-titanium curved needles come out from the shaft, one for each quadrant. (c) The screen allows the surgeon to monitor the energy delivered (465 kHz, 2–5 W) from each needle for 60 seconds. Energy to the electrodes is automatically discontinued when the temperature reaches 85°C. (d) The curved needles are inserted into the level of the IAS to deliver the RF energy. The thermal injury occurs at the tip of the needle while the mucosa is cooled by chilled water at the base of each needle. (e) Treatment starts from the dentate line and it is repeated four times (16 lesions per level) and moving cephalad every 5 mm for a maximum of four to five levels. (f) Three-dimensional visualization of areas where the energy has been delivered. (Courtesy of Mederi Therapeutics © 2015.)

Table 93.3 Radiofrequency mid- and long-term outcomes

Author	N#	F/U	Outcome measure	Overall improvement	CR%	Definition of CR	Complications
Takahashi et al. ⁷	10	12	CCF/Wexner-FIS FIQL SF-36	13.5 to 5	80	>50% reduction in WIS	Four bleeding
Takahashi et al. ¹⁰	10	24	CCF/Wexner-FIS FIQL SF36	13.8 to 7.3	70	>50% reduction in WIS	None
Takahashi-Monroy et al. ¹¹	18	60	CCF/Wexner-FIS FIQL SF-36	14.4 to 8.3	84	>50% reduction in WIS	None
Efron et al. ⁸	50	6	CCF/Wexner-FIS FIQL SF-36 VAS	14.5 to 11.1	60	>10% reduction in VAS	Two mucosal ulcerations, 26 minor
Felt-Bersma et al. ¹³	11	12	SMS	18.8 to 15	55	Subjective improvement	Pain: 67%, Hematoma: 33%, Diarrhea: 7%
Lefebure et al. ¹⁴	15	12	CCF/Wexner-FIS FIQL SF-36	14.1 to 12.3	13	>50% reduction in WIS	None
Kim et al. ¹⁵	8	6	FISI FIQL	35.1 to 25.6	38	Subjective improvement	7
Ruiz et al. ¹⁶	24	12	CCF/Wexner-FIS FIQL	15.6 to 12.9	12.5	>50% reduction in WIS	None
Lam-Visscher et al. ⁵	31	36	SMS FIQL	18 to 15	6	>50% reduction in SMS	Hematoma: 8, Urinary infection: 1, Diarrhea: 7

Abbreviations: CR, clinical response; FIQL, fecal incontinence quality of life score; FISI, fecal incontinence severity score; F/U, follow-up (months); N#, number of patients involved; SMS, St. Mark's score; VAS, visual analog scale; CCF/Wexner-FIS: Cleveland Clinic Florida/Wexner-Fecal Incontinence Score.

Table 93.4 Results of injectable agents

Author	n	Material used	F/U (months)	CCF/Wexner-FIS	
				Before	After
Shafik ¹⁷	11	PTFE	24	63% improved	
Shafik ¹⁸	14	Autologous fat	24	85% improved	
Malouf et al. ²¹	10	Bioplastique	6	30% improved	
Tjandra et al. ²²	82	Silicone	12	50% improved	
Tjandra et al. ²³	20	PTQ	12	12	4
Weiss et al. ²⁴	10	ACYST	22	13	10
Sorensen et al. ²⁵	33	Silicone	12	13	10
Davis et al. ⁵²	18	Durasphere	29	11.8	8
Chan et al. ²⁶	7	PTQ	14	9–14	1–5
Stojkovic et al. ²⁷	73	Contigen	12	10	6
De la Portilla et al. ²⁹	20	PTQ	24	13.5	9.4
Maeda et al. ³⁹	10	Bulkamid	19	15	12
		Permacol		16	15
Schwander et al. ⁵³	21	Hyaluronic	20	17	12
Ratto et al. ⁵⁴	14	Gatekeeper	33.5	12.7	5.1
Graf et al. ³⁰	125	NASA-Dx	12	52% of patients had 50% or greater decrease in number of fecal incontinence episodes	
Rosato et al. ⁵⁵	53	Polyacrylate polyalcohol	36	10	4.0

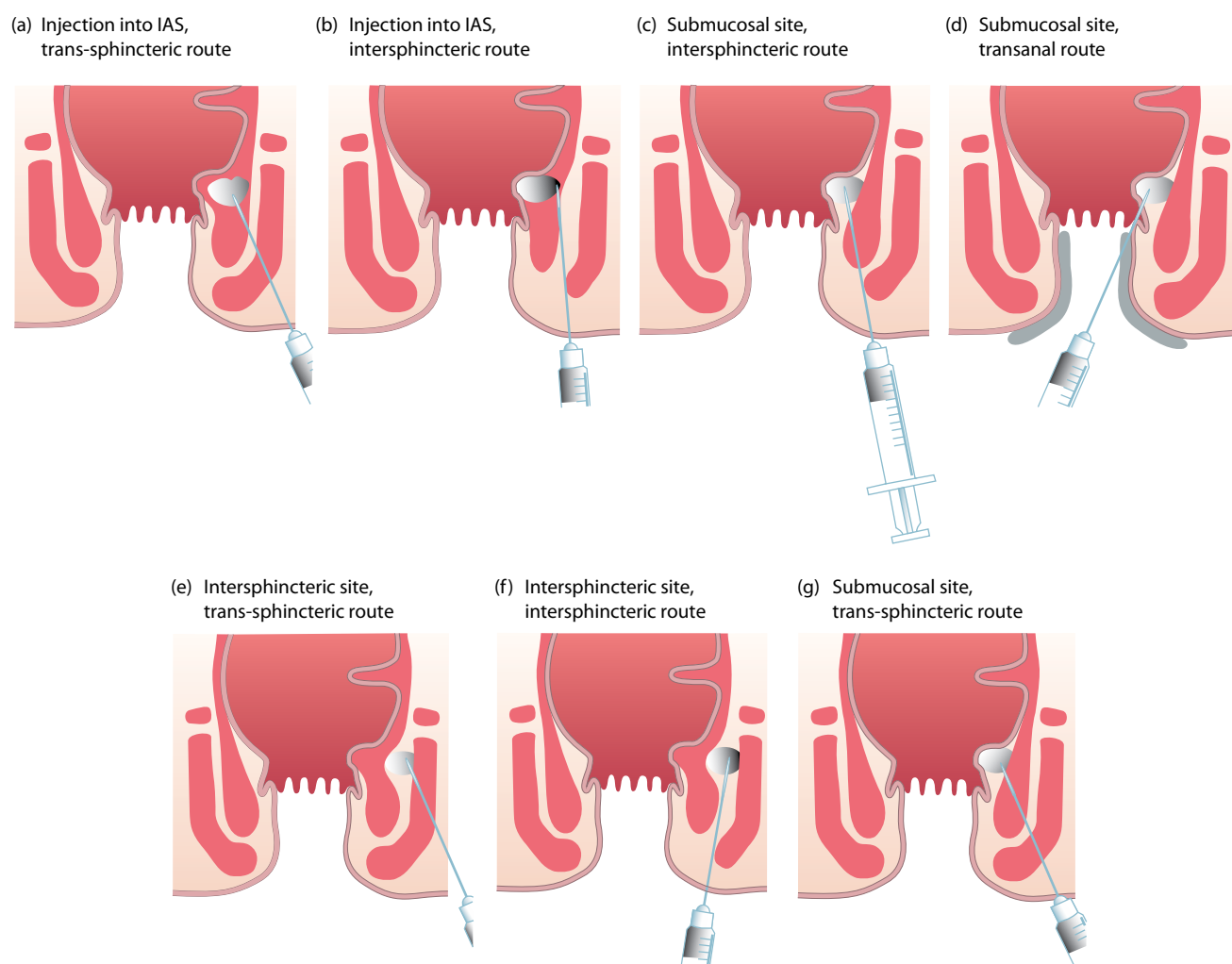
Table 93.5 Short- and long-term success of bulking agents

Agent	Number of studies	Morbidity (%) <i>n</i> = 1030	Short-term success %	Long-term success %
PTQ	21	6.0	75.8	63.4
Durasphere	7	4.4	53.3	43
NASHA	4	1.9	44.6	–
Permacol	3	0	82	100
Bulkamid	1	0	100	0
Coaptite	1	0	80	–
Contigen	2	0	63	–
EVOH	1	1.9	47	–
Autologous fat	2	0	100	100

Note: EVOH, ethylene vinyl alcohol.

postoperative antibiotics, postoperative laxatives, and type of anesthesia with complication rates and outcomes. While 39 studies were identified that evaluated 1,070 patients, only five randomized controlled studies were included. Efficacy was grouped as failure or success and was determined by the authors of each review article. A total of 69.7% of patients had a positive immediate response (56.3% “good response,” 13.4% complete continence). At follow-up, a smaller group of patients still experienced significant benefit: 45.2% reported a persistent “good response,” while 12.3% remained completely continent. **Table 93.5** shows the success and complication rates reported by the type of bulking agent used (139 patients, 13.5%). The most common complications were pain (6.5%) and leakage of injected material (5.6%).

Univariate analysis showed that the type of bulking agent (PTQ > others), route of injection (intersphincteric > transanal > transsphincteric), use of postoperative antibiotics, type of anesthesia (local > sedation > general), positioning

**Figure 93.2** Described site and route of injections. (With permission from Hussain ZI et al. *Br J Surg* 2011;98:1526–36.)

of the patient (left lateral > Kraske), and absence of postoperative laxatives were all significantly associated with an increased risk of complications. On multivariate analysis, only intersphincteric injection was associated with a greater likelihood of postoperative complications (odds ratio [OR] 3.40 1.62–7.12, $p = 0.001$). The authors suggested this could be secondary to the greater distance from the anal verge during transsphincteric injection, leading to a lower infection rate. Another explanation could be that the increased vascularity of the intersphincteric space may increase the risk of bleeding/hematoma.

Functional outcomes were also evaluated by a logistic regression analysis. Univariate analysis determined that eight variables affected the overall results: agent type (PTQ > others), site of implantation (intersphincteric > submucosal > IAS directly), transsphincteric injection, use of pre- and postoperative antibiotics, type of anesthesia, positioning of the patient, and the absence of postoperative laxatives. Multivariate analysis showed that only two variables remained statistically related to better function: the type of agent (PTQ and Coaptive) and the type of anesthesia. Interestingly, the use of local anesthesia was shown to be associated with worse functional outcome (OR 0.18, 0.05–0.59, $p = 0.001$), suggesting that general anesthesia or sedation may permit better exposure and, therefore, a more accurate injection. The only predictor of long-term durability was found to be the use of postoperative laxatives. This may be explained by the possibility that straining in the immediate postoperative period could promote migration and fragmentation of the bulking agent, limiting its effectiveness.

The routine use of ultrasound as a guide for more accurate directed injection has been described but has failed to obtain statistical relevance. Although not proven, we recommend ultrasound-guided injections in patients who have previously undergone any FI surgery in order to facilitate positioning the implants under direct vision. Unfortunately, recent reports have shown very discouraging long-term results with this technique.³³ In a small, but well-designed observational study, 19 patients underwent injection with three different agents (Durasphere versus PTQ versus Solesta). Manometry and endoanal ultrasound were performed immediately after injection and at 1- and 7-year follow-up, and patients were then matched according to their CCF/Wexner-FIS. The authors reported no differences seen on ultrasound among the different agents after 1 and 7 years. While the mean injected volume was 6.7 ± 1.7 mL during the procedure, only 0.97 ± 0.5 mL was detected at follow-up. Despite the initial improvement at 1 year, patients reported the same baseline preinjection CCF/Wexner-FIS after 7 years. Furthermore, resting and squeezing pressures did not differ when comparing preoperative data with long-term follow-up. Injectables may not be as effective as RF, since the method of injection is variable, operator dependent, and its effect wanes over time. One theoretical advantage of bulking agent injection as compared to RF is the ability to treat patients in the outpatient setting without

general or regional anesthesia or deep conscious sedation. Overall, between the two options, RF seems superior.

Sacral nerve stimulation

INDICATIONS AND BENEFITS

First utilized in patients with urinary incontinence, sacral nerve stimulation (SNS) was also found to improve FI symptoms in these patients after implantation. Although Matzel et al. first reported success in three patients in 1995,³⁴ FDA approval was not obtained until 2011, following the Wexner et al. publication of the results from a 120-patient multicenter North American trial.³⁵

Unlike other therapeutic modalities for FI, SNS is appealing due to high success rates and the possibility of reversal with minimal adverse effects to the patient, if ineffective. Because there is no manipulation of tissue around or near the anal canal, there is a decreased possibility for sphincter scarring or infection. For this reason, some authors have proposed that this technique should be considered as a first-line therapy due to observed improved continence and decreased rate of outlet obstruction. When considering a patient for this procedure, the ASCRS guidelines state that a patient must have moderate-to-severe FI (CCF/Wexner-FIS 7–20) and must have failed prior conservative management.⁴ Patients with previous pudendal nerve damage or neuropathy, a prior sphincteroplasty, or a small-to-moderate existing sphincter defect may experience a good outcome with SNS.³⁶ Success with SNS has also been observed after rectal resection,^{37,38} pelvic radiation therapy,³⁹ and in selected cases of spinal cord injury.⁴⁰ Contraindications may include mechanical obstruction, congenital anorectal malformations, untreated rectal prolapse, deformity of the sacral spine, or local skin diseases.⁴

MECHANISM OF ACTION AND TECHNIQUE

While the mechanism of action is still uncertain, there are likely three main outcomes of stimulation: activation of a somato-visceral reflex, direct effect on the anal sphincter complex, and afferent nerve modulation. These things may increase rectal sensation through chemoreceptors and also affect the continence mechanism through a pathway affecting brain stimulation. Although unclear, it has also been shown that patients in whom the SNS device was deactivated or explanted continued to experience relief of their FI symptoms.⁴¹ Altomare et al. studied 19 patients; after deactivation of their stimulator, 10 patients had recurrence of symptoms after 3.4 months, but 9 patients had an unchanged incontinence score after 1 year.⁴¹

SNS consists of two outpatient procedures. The first stage is a percutaneous quadripolar electrode placement. If the patient has a $\geq 50\%$ reduction of FI symptoms, the device is definitively implanted in the second stage. After the patient is placed in the prone position and the lower back to the upper thighs are prepped and draped, exposure of the lower

buttock and feet is essential for proper verification of placement. The ground pad is placed on clean skin and connected to the test stimulation cable. External neurostimulator amplitude should be decreased to zero. After identification of the S2, S3, and S4 nerve foramina using bony landmarks, fluoroscopy, or diagnostic ultrasound, the insulated foramen needle is inserted into the S3 foramina at a 60° angle to the skin (Figure 93.3). The needle should enter the foramina perpendicular to the bony surface in order to position the needle parallel to the nerve. The depth of the needle should be no more than 4 cm, with the tip of the needle right past the sacrum. The test stimulation cable is then used to confirm placement, with gradual increase of intensity until plantarflexion of the great toe or bellows (flattening of the buttock groove from dropping of the pelvic floor) are observed. At this time, the patient is asked where he or she feels the stimulation, with sensation in the vagina, scrotum, or rectum/anus confirming optimal placement. If desired responses are not seen, consider increasing or decreasing the depth of the needle or changing the angle. Once testing is complete, replace with the lead via the Seldinger technique and confirm placement with imaging (Figure 93.4). Next, the various electrodes on the lead (0, 1, 2, 3) should be tested while observing responses in the buttocks and feet. When the lead is in place, the tines will have deployed, making repositioning difficult. If relocation is required, the lead will need to be entirely removed and replaced. Ideally, the lead should have a “hockey-stick” appearance with a slight curve of the tip of the lead pointing laterally. At this time, a pocket in the upper buttock is created at the appropriately marked site. The pocket should be deepened to the gluteus fascia, and ideally contralateral to the side on which the patient sleeps. The remaining wire is tunneled out through

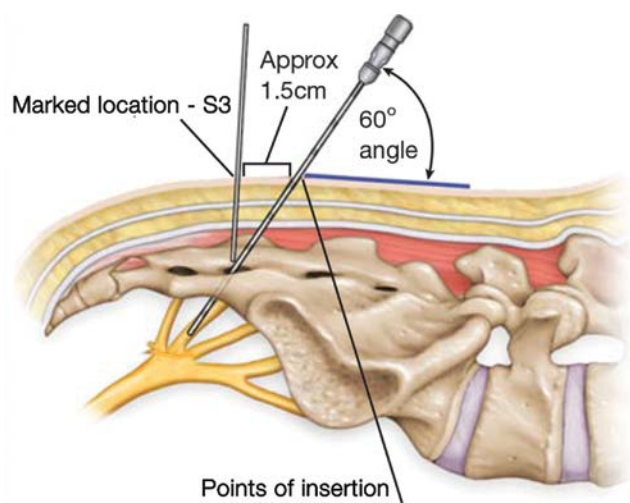


Figure 93.3 Needle insertion and direction. (With permission from Wexner SD et al. [eds.]. *Colon and Rectal Surgery: Abdominal Operations [Master Techniques in Surgery]*. Philadelphia, PA: Lippincott Williams and Wilkins/Wolters Kluwer; 2011.⁶⁵)

a separate site, and the incision is closed. It is important to secure the external wire to the skin so that over the course of the following 2-week trial, the lead is not dislodged.

After the 2-week stage 1 trial period is successful, the device can be definitively implanted. The percutaneous extension is removed, and the pocket is reopened, being careful to protect the lead from secondary stimulation if using electrocautery. The neurostimulator is placed in the pocket with the etched identification side upward; it is important to ensure that the lead has a gentle curve and is not bent. The incision is closed in layers after irrigation. Postoperatively, the patient must be provided with a patient programmer and identification card.

PREVENTING FAILURE AND COMPLICATIONS

Despite encouraging results with SNS, several pitfalls related to the technique and postoperative management have been described and should be considered. A recent review by Maeda et al.⁴² analyzing 94 articles for a combined total of 1,661 patients showed that adverse events are related to worse functional outcome. For optimum success, SNS requires continuous and ongoing maintenance, and may need continued reprogramming after implantation according to patient symptoms. Stimulation parameters should be well documented and include details of amplitude, frequency, pulse width, and stimulation mode, similar to the goal achieved by an effective stimulus (sensory response and area). The battery may need to be replaced every 5–8 years, with increasing frequency for those devices on increased amplitude.

Maeda et al.⁴² found a postoperative complication rate of 12.1%, including surgery-related complications and loss of efficacy. Surgery-related adverse events include infection, hematoma, skin erosion or wound dehiscence, and pain (most common). It is important to distinguish the cause of the pain, whether it is due to the surgical site (such as a hematoma or seroma) or is secondary to the electric stimulus. Pain at the battery site is mostly described in patients with a low body mass index (BMI)⁴³ due to the volume of subcutaneous tissue. In these cases, the stimulator may need to be relocated to a deeper location or contralateral buttock. In rare events, pain can be related to protrusion of the lead or the wire connecting the lead to the battery. In these cases, anchoring the wire to the bone or the fascia may help to prevent this problem.⁴² As with any implanted foreign body, there is a risk of infection, accounting for 3.9%–10.8% of adverse events.^{42,44} Wexner et al. reported that approximately half of their cohort recovered either spontaneously or with the use of antibiotics, while the other half did require permanent explantation of their device.⁴⁴ If explantation is necessary, it is essential to also excise the capsule surrounding the stimulator along with the device.

Lead migration has become a rare event since tined leads replaced fascial or bone anchoring⁴⁵; however, several series reported lateral or anteroposterior displacement. It is important to compare anterior-posterior and lateral x-rays of the pelvis with the original intraoperative x-rays in order

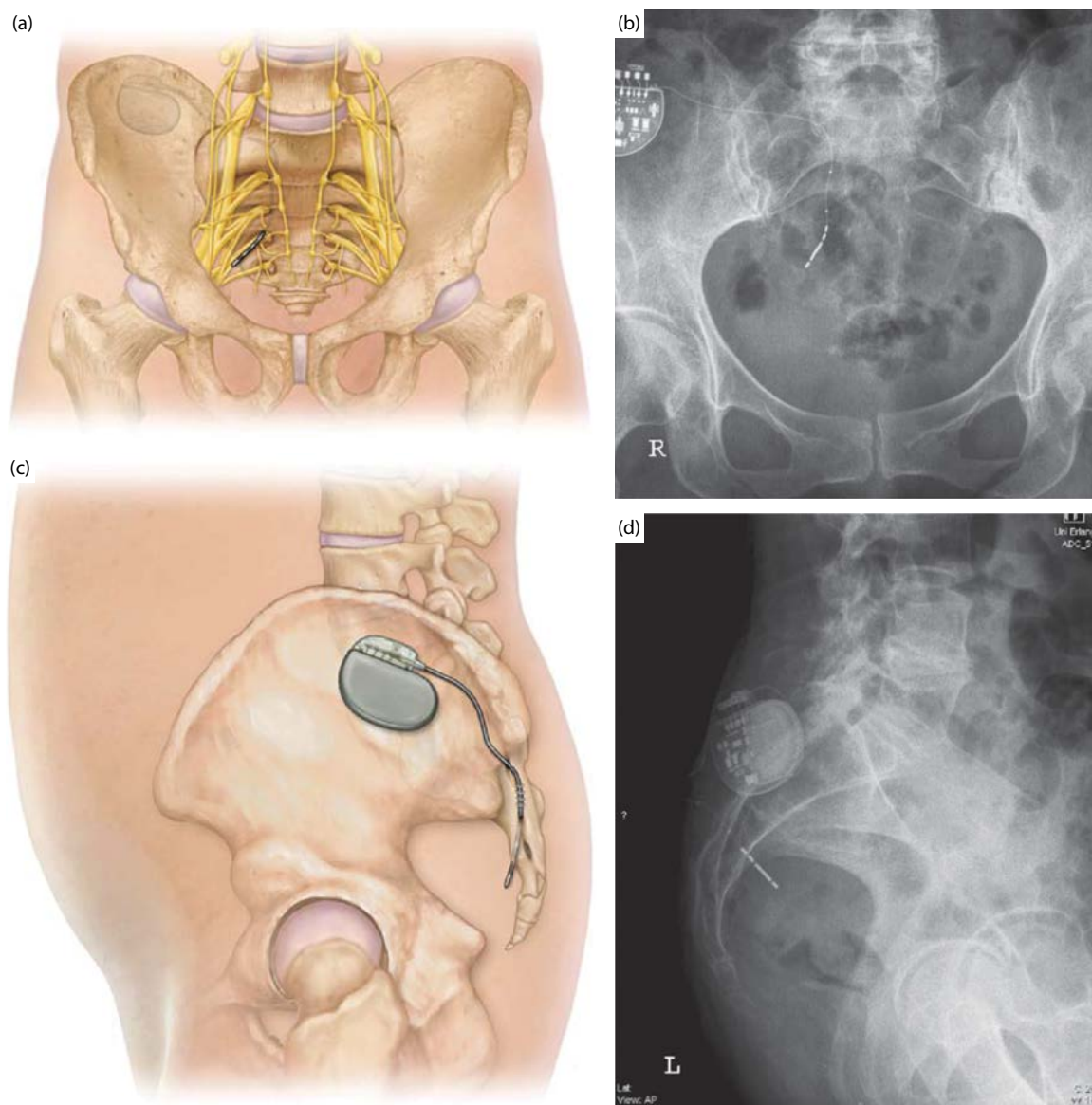


Figure 93.4 Lead position. (a) Anterior view, art work; (b) posteroanterior x-ray; (c) lateral view, art work; (d) lateral x-ray. (With permission from Wexner SD et al. [eds.]. *Colon and Rectal Surgery: Abdominal Operations [Master Techniques in Surgery]*. Philadelphia, PA: Lippincott Williams and Wilkins/Wolters Kluwer; 2011.⁶⁵)

to assess any migration. If the degree of migration is minimal, a positive effect can be achieved simply by changing to polar combinations, which are closer to the sacral nerve root.⁴⁶ If there has been anterior migration, it has been suggested that backing out the lead should be combined with reinforcement using a grid lock or twist lock to the lumbosacral fascia, which may overcome possible bone laxity or atrophy.⁴⁷ The same strategy has been suggested for patients with BMI < 19, postulating reduced soft tissue and fascial density.⁴⁸

If the device has lost effectiveness, a few simple circuit checks should be performed. Abnormal impedance (<50 ohms or >4000 ohms) can be related to electrical system failure. Elevated impedance is suggestive of an open

circuit (lead breakage or disconnection), while low impedance can be secondary to a tight connection or surrounding fluid affecting the circuit. Regardless of the impedance, if evoked sensation and motor response are present, no surgery is advocated. Maeda et al.⁴² developed a useful stepwise process in order to systematically approach this problem. When loss of efficacy occurs, as previously mentioned, the first action is to obtain a radiographic image to verify the lead position. In case of displacement, surgery is necessary. If the position is unchanged from that found during the intraoperative images, the surgeon can try reprogramming the device until an effective stimulus (correct intensity in the correct anatomical spot) is delivered. If, despite initial successful reprogramming,

Table 93.6 Long-term results of sacral nerve stimulation

Author	F/U (months) median	Number of patients		%	
		At Baseline	At Follow-up	>50% improvement ^a	Full continence
Maeda et al. ⁵⁶	60	141	101	55	nc
George et al. ⁵⁷	114	23	19	na	52
Moya et al. ⁵⁸	56	52	50	96	nc
Matzel et al. ⁵⁹	118	12	9	78	44
Lim et al. ⁶⁰	51	53	41	nc	nc
Hollingshead et al. ⁶¹	60	86	18	21	na
Vallet et al. ⁶²	44	32	23	72	4
Duelud-Jakobsen et al. ⁶³	46	158	91	75	36
Altomare et al. ⁶⁴	74	60	52	na	18
Hull et al. ⁵¹	48	120	77	87	34
Uludag et al. ²⁰	84	50	36	84	nc
Total	84 (44–118)	787		71.3 (21–96)	36 (4–52)

Abbreviations: F/U, follow-up; na, not available; nc, noncalculated.

^a 50% improvement means 50% reduction in fecal incontinence episodes as compared to before SNS implantation.

the patient is still complaining of FI, a stimulation hiatus (4–16 weeks), followed by reprogramming, can be tried. If there is no considerable effect observed after this, consideration should be made for repositioning the permanent lead regardless of the radiological finding. Patients in whom the lead has migrated or become displaced may prefer reimplantation rather than explantation, contingent on their prior experience with the device.

LONG-TERM RESULTS

Only a few studies have explored the long-term outcomes of SNS, despite many studies that report success (Table 93.6). Altomare et al. recently published the largest multicenter long-term analysis, including patients from 15 international centers.⁴⁹ Long-term success was reported in 194/272 patients (71.3%) with WIS decreasing from 16 (13–18) at baseline to 6 (4–9) after SNS implantation after a 60-month follow-up. After device implantation, 79 patients (29%) experienced minor complications. After logistic regression, no preoperative physiologic or demographic parameter (sphincter defect, number of FI episodes, baseline WIS, implant side, gender, or age) correlated with prolonged success. Only age was found to be inversely proportionate to immediate success after implantation, but the same effect was lost when analyzing the long-term follow-up data. Unfortunately, only small series have described surgical alternatives in case of failure of SNS.⁵⁰ In our practice and according to the current literature, in case of failure of SNS, only replacement techniques or permanent diversion are viable alternatives.

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Laparoscopic approach to inguinal and abdominal wall hernia



Lejaren à Hiller, *Vesalius*, 1944. Plate published in *Surgery through the Ages: A Pictorial Chronicle* (New York: Hastings House, 1944).
(© 1944 Davis and Geck Inc. Image courtesy Visual Studies Workshop, Rochester, NY.)

This artistic photograph represents a well-known figure from the history of anatomy, Andreas Vesalius (1514–64). The image is part of a series of seventy photographs created by Lejaren à Hiller and published in his 1944 book *Surgery through the Ages*. As explained by historian Bert Hansen, Hiller's work was a response to the surge in interest in medical history in mass culture in the United States between the 1920s and 1940s. This was reflected in both images and literature and focused on the “heroes” of medicine from prior eras, like Vesalius. Hiller (né Jaren Hiller; 1880–1969) was a commercial photographer with fine art ambitions. Borrowing from pictorialist photography (a style that emphasized the artistic values of photography), he created images that aimed to estheticize a range of important figures from surgical history. Through his dramatic reenactments, he brought historical scenes to life using effects that mimic those used in romantic and history paintings, including sharp contrasts in lighting, painted backdrops, and often (although not depicted here), the use of seductive nude female models.

Vesalius (né Andries van Wesel) was a Flemish physician and author of *De humani corporis fabrica* (*On the Fabric of the Human Body*; 1543), an influential tome on human anatomy. Earning his MD in 1537 from the University of Padua, he immediately became the chair of surgery and anatomy there. As depicted in this image, Vesalius encouraged his students to take a hands-on approach to learning by performing human dissections, becoming the first to lecture while simultaneously dissecting a cadaver. Hiller's theatrical lighting, reminiscent of the Italian baroque master Caravaggio, as well as the curious gazes of the onlookers, only serve to further dramatize and estheticize Vesalius's virtuosity.

Bert Hansen, “Medical History's Moment in Art Photography (1920 to 1950): How Lejaren à Hiller and Valentino Sarra Created a Fashion for Scenes of Early Surgery,” *Journal of the History of Medicine and Allied Sciences* 72, no. 4 (August 2017): 381–421, doi: 10.1093/jhmas/jrx037.

Laparoscopic totally extraperitoneal hernia repair

EDWARD L. FELIX

INTRODUCTION

Modern inguinal hernia repair, which began in the 1800s with Bassini, was reinvented with the advent of mesh repairs in the 1900s, and today is one of many procedures performed with minimally invasive laparoscopic techniques. Laparoscopic repairs were initially transabdominal, but in an effort to avoid the potential complications of crossing the peritoneal cavity, a totally extraperitoneal (TEP) approach was developed. The purpose of this chapter is to describe the varying TEP approaches, the benefits of each, the risks and complications, and how to avoid these complications.

TECHNIQUE

The surgeon stands on the side opposite the hernia with the patient's arms tucked. An incision is made just below the umbilicus off the midline, usually on the side of the hernia. The external oblique fascia is incised and the rectus muscle retracted laterally to expose the posterior fascia. The surgeon slides a balloon dissector over the posterior fascia until the dissector reaches the extraperitoneal space. After the pubis is palpated with the tip of the dissector, the balloon is slowly inflated, watching the dissection through the balloon. The balloon is deflated, removed, and replaced with a Hasson trocar, and the extraperitoneal space is inflated to 12 mm with CO₂. Under direct vision, 5 mm trocars are placed in the midline for dissection. The middle trocar is placed as close to the Hasson as possible to allow the lowest trocar to be placed high enough to be free of the mesh. A second option is to place one of the trocars in a lateral position. Some surgeons prefer not to use a balloon dissector and place the trocars under direct vision after dissecting the space by sweeping the camera from side to side. This technique is more difficult and may take a little

longer, but it can decrease the overall cost of the procedure by eliminating one of the disposables. A new approach called extended totally extra-peritoneal (ETEP) modifies the trocar placement by placing the camera port in the upper abdomen giving the surgeon a larger extraperitoneal space with which to work.¹ This theoretically makes doing larger or incarcerated hernias easier.

The dissection of the extraperitoneal space is completed using blunt and sharp dissection of the filmy attachments. The pubis and Cooper ligament are exposed. This anatomical landmark helps orient the surgeon before performing further dissection. If the angle between the pubis and iliac vessels is obscured by tissue, it means that there is a femoral hernia that needs to be carefully reduced. If there is a direct hernia, it is reduced at this time in the dissection ([Figures 94.1 and 94.2](#)). The direct sac is allowed to retract into the fascial defect. It should not be ligated because the tip of the bladder may be inadvertently trapped in the ligature.

The lateral floor dissection begins with identification of the inferior epigastric vessels. If the vessels were taken off the wall by the balloon, they can be ligated and transected to make mesh placement easier. Loose connective tissue and fat are swept off the wall just lateral to the vessels, and the peritoneum is pushed posteriorly and superiorly. This maneuver exposes the cord structures and indirect sac if there is one. When a lipoma is present, it will be lateral to the cord structures and cover the testicular vessels. The lipoma must be pulled out of the internal ring and left in the retroperitoneum superior to the operative field. This prevents leaving a retained lipoma, one of the most common causes of recurrence.² Sometimes the neck of the lipoma is very thin, even though the distal portion is extremely large. The surgeon must therefore gently dissect out the fat lateral to the cord structures to be assured a lipoma is not left behind. The lipoma fat will easily dissect off the cord while the fat of the cord is adherent to the vessels of the cord. Because the femoral branch of the genitofemoral nerve and the lateral

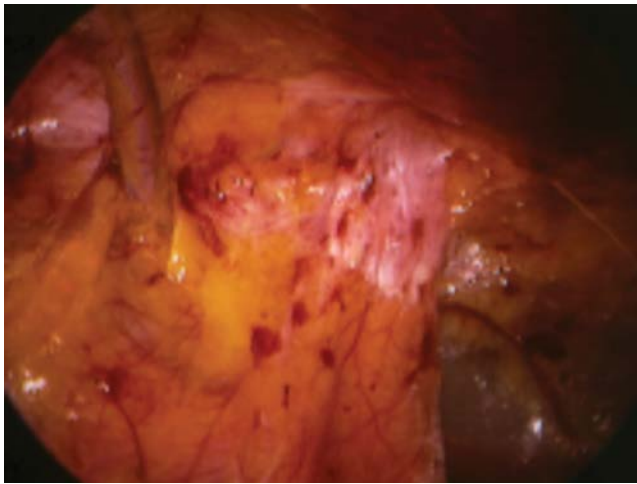


Figure 94.1 A view of the partially reduced direct hernia on the left side.

cutaneous nerve lie beneath the lipoma, cautery should not be used in this area of dissection.

The indirect hernia sac is anterior and lateral to the cord structures. The sac must be carefully teased cephalad without injuring either the vessels or the vas deferens. The vas will be on the medial aspect of the sac. The peritoneum or sac is dissected far enough that it will not be left under the mesh. If peritoneum is left under the mesh, it will eventually lift the mesh, leading to recurrence. If there is a large sac, it can be placed on top of the mesh after the mesh is positioned. This actually helps anchor the lower aspect of the mesh. A small hernia sac is delivered out of the internal ring by stripping it off the surface of the testicular vessels and vas deferens. If the indirect sac is quite long and difficult to dissect out of the canal,

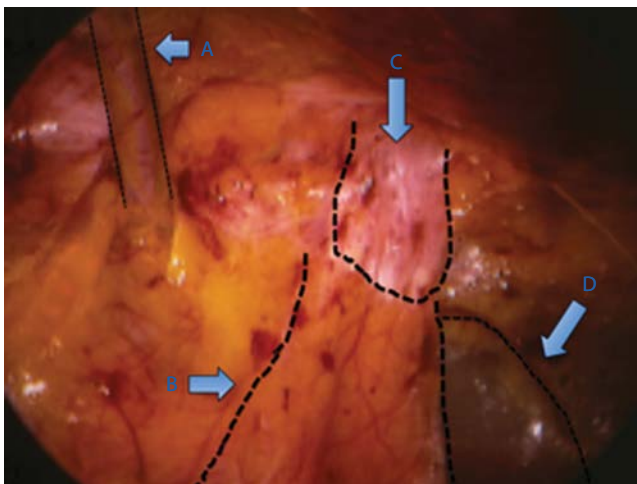


Figure 94.2 Dissection of the extraperitoneal space: (a) the inferior epigastric vessels; (b) the peritoneum adherent to the sac; (c) the direct sac; and (d) the pubis.

it can be opened and carefully transected, remembering that the testicular vessels on the lateral aspect and the vas deferens on the medial side will be adherent to the sac. It is therefore important to identify these structures before completing the transection of the peritoneum. The open peritoneal sac is ligated with an Endoloop at this point in the dissection or can be deferred until it is time to evacuate the CO₂. If intraperitoneal CO₂ obscures the field of vision, the gas can be removed using a Veress needle after ligation of the sac. Unlike in the transabdominal preperitoneal approach, in the TEP approach, the surgeon cannot definitively determine whether there is an indirect sac until the entire posterior dissection is complete. This dissection of the peritoneum must therefore be performed completely and the edge of the peritoneum visualized in every patient.

When the posterior dissection is complete, the surgeon has an unobstructed view of all three potential hernia sites: the direct, indirect, and femoral (**Figures 94.3 and 94.4**). The space between the pubis and the bladder has been established so that the lower aspect of the medial portion of the mesh will be held in place by the bladder after positioning the mesh. If an obturator hernia is present, this dissection is completed before the mesh is placed into the extraperitoneal space. The indirect hernia sac and the lipoma will be in the space cephalad to the area to be covered by the mesh.

The mesh portion of the repair begins by removing the scope, grabbing the mesh with a laparoscopic grasper, pulling it into the extraperitoneum, and then replacing the scope to push the mesh completely into the dissected extraperitoneal space. The type of mesh used is the surgeon's choice and varies partially according to the type of fixation chosen. Whether lightweight mesh with larger pore size is used, conventional polypropylene mesh, or a polyester mesh is still debatable. The risks and benefits of



Figure 94.3 The completed dissection of the posterior floor on the right side.

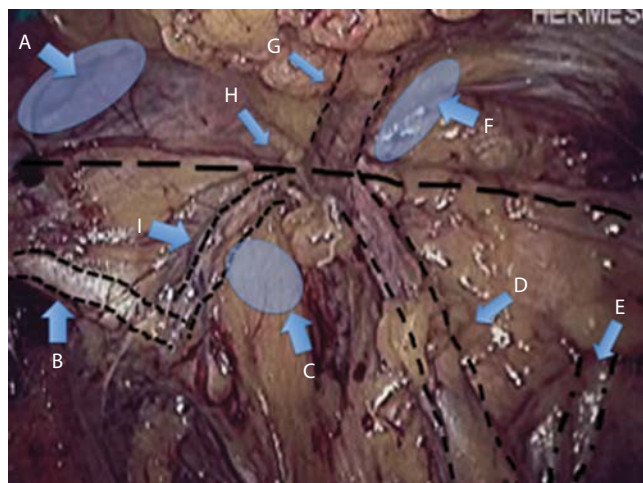


Figure 94.4 Posterior dissection of the peritoneum: (a) direct hernia; (b) the pubis; (c) location of potential femoral hernia; (d) testicular vessels; (e) nerves; (f) location of internal ring; (g) inferior epigastric vessels; (h) iliopubic tract; and (i) vessels crossing pubis and Cooper ligament.

each are still being studied. Lighter-weight meshes were proposed to reduce postoperative pain, but randomized studies with long-term follow-up have only shown that there may be an early difference in pain scores and that disappears with time.³ The larger pore mesh may actually have a higher incidence of failure in larger direct hernias.⁴ Polyester mesh that is softer than polypropylene has also been proposed, but again studies to support the advantage of one mesh over another are lacking. Another choice is whether to use a preformed mesh that conforms to the pelvis. It is more expensive than flat mesh, but it may have the advantage of being faster to deploy and not require fixation, thus reducing its overall cost. If a preformed mesh is chosen, it is useful to mark the medial inferior edge before it is placed into the trocar in order to expedite positioning of the mesh.

After the mesh is placed in the extraperitoneal space, it must be manipulated into position to cover the entire floor with a significant overlap of the direct, indirect, and femoral defects as well as the pubis (**Figure 94.5**). As mentioned previously, the mesh must be placed between the bladder and the pubis to prevent it from being lifted up by an expanding bladder. The size of the mesh is dependent on the patient's size, but one of the major causes of failure is using too small of a mesh.⁵ In general, it should be at least 15 cm in each direction. Once the mesh is properly positioned to cover the entire wall, it must lay flat against the wall without any folds or ripples. Wrinkles in the mesh may lead to postoperative pain or increased shrinkage of the mesh.

Only after the mesh is in perfect position should the surgeon begin to fix the mesh, if fixation is to be used. The alternatives at this juncture are no fixation, sharp



Figure 94.5 Positioned mesh: (a) the bladder; (b) the pubis; (c) direct defect; and (d) internal ring.

fixation (permanent or absorbable), or self-adhering mesh. Randomized studies have not shown one technique to be superior over another in terms of recurrence.⁶ Nonpenetrating fixation has been shown to decrease in pain scores without increasing recurrence rates when compared to permanent fixation, but none of the noninvasive approaches have been shown to be superior to no fixation in a randomized study.

If fixation is chosen, is absorbable fixation superior to permanent fixation or is one type of tack or staple the best? Unfortunately, there is no evidence that any one technique or device is the best. What is important is proper placement of the fixation. The abdominal wall must be palpated while the anchors are being placed to assure they are placed above the iliopubic tract in order to avoid neural injury. Unfortunately, even when fixation is properly placed, there is a risk of injuring an aberrant nerve⁷ or penetrating too deeply and catching an anterior one. Absorbable tacks were developed to avoid long-term nerve entrapment, but the inflammatory response induced by these anchors may be just as harmful. The number of fixation points needed to anchor the mesh has been seriously reduced since the advent of TEP repair. If fixation is required, it only needs to be placed into Cooper ligament, above the direct hernia and possibly in the lateral wall above the iliopubic tract.

An alternative approach is to anchor the mesh with glue. At this time, this is an off-label but effective approach.⁸ This approach allows for proper placement of the mesh and then fixation without injury to the nerves. In addition, there is a potential for reducing lateral recurrence that might be caused by roll-up of the mesh or pushing of the mesh into a large direct defect. These are still only potential advantages however, since the trials to prove that glues are more effective than no fixation at all have not been done. The last alternative is to use a self-adhering mesh. It has been shown to be effective in a small series of patients⁹ but is the most difficult

approach to master. Only time will tell if this approach is more widely adopted and the studies needed to prove its worth are completed.

The last step in the TEP repair is as essential as any of the previous steps outlined in this chapter to assure the repair will have the lowest incidence of recurrence possible. The CO₂ must be evacuated slowly while watching the peritoneum come up against the mesh. If the expanding peritoneum begins to lift the mesh, the space should be re-insufflated and the peritoneal dissection carried further cephalad. The process of releasing the CO₂ should then be repeated. If possible, the lipoma and indirect sac are placed on top of the mesh to help hold it down.

COMPLICATIONS

The best way to prevent complications is to understand why they occur. The most important one to avoid is chronic postoperative pain. The two leading causes of pain are sharp fixation placed below the iliopubic tract or placed too deeply into the anterior nerves and mesh that has hardened, irritating any of the retroperitoneal nerves. Both of these complications can be reduced by proper technique. Careful placement of fixation or avoiding penetrating fixation altogether will decrease the first and smoothing out the mesh and watching its position as the carbon dioxide is evacuated should eliminate the second.

Injuries to the bladder have been reported. These are usually due to placing the balloon dissector when the patient's

bladder is distended or inserting the dissector too deeply into the space between the pubis and the bladder. By having the patient void before anesthesia and then palpating the pubis with the dissector when it is placed, these complications should be prevented.

The final complication to be avoided is recurrence. Meticulous dissection of the anatomy, recognition of all potential hernias, and removing the lipoma from the indirect defect in every patient is essential before mesh is placed. When placing the mesh, it must be large enough to extend at least 3 centimeters beyond the hernia defects, cover the entire floor, and not be curled up by the bladder or peritoneum. With experience, recurrence rates after TEP hernia repair can be less than 1%, and the incidence of chronic pain less than after open repairs.¹⁰

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Technique of transanal-assisted colon resection and rectopexy

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INTRODUCTION

Rectal prolapse is a frequent problem in benign pelvic floor disorders.^{1,2} Often the background is a year-long chronic obstipation with excessive periods of straining during defecation combined with insufficiency in the tissues of the pelvis and rectum, causing sliding of the rectal mucosa on the underlying muscular wall of the rectum and surrounding pelvic structures.² Patients can present with an internal or external rectal prolapse depending on the stage of development and the failure of the individual structures.² Once the prolapse is manifest, conservative therapy is limited.² The operative treatment for these functional anatomic changes was established by laparoscopic techniques many years ago. Two main techniques have emerged as most successful procedures: the resection rectopexy similar to the established technique from open surgery and the laparoscopic anterior rectopexy with mesh.³⁻⁶

The selection of patients for these operations requires an extensive diagnostic work-up to verify the indication for surgery. The diagnostic work-up should consist of a proctologic investigation, endo-sonography to verify the status of the anal sphincter system, an anorectal manometry, a Hinton test to verify a possible coexistence of a slow transit constipation, and dynamic MRI defecography.

With the advent of natural orifice transluminal endoscopic surgery (NOTES), a transanal-assisted minimally invasive technique was developed and established in clinical practice.^{7,8} The technique is based on the principle of resection of the redundant sigmoid combined with a rectopexy, performed in a hybrid laparoscopic and transanal technique.⁹⁻¹¹

TECHNICAL CONCEPT

The principle of NOTES is the use of a natural orifice as an entry port into the abdominal cavity to avoid or reduce access trauma through the abdominal wall as much as possible.^{7,8} As a consequence, the natural orifice should be the main port for larger caliber instruments during the entire procedure, as well as the port for specimen retrieval. Transabdominal access should be restricted to as few ports as possible, and with a maximum of 5 mm diameter. This can be achieved by using a special transanal trocar with a diameter of a few cm, allowing for the application of graspers, endoscopes, and staplers, and for specimen retrieval.¹¹

Only a few transabdominal trocars are used for dissection work, especially for the application of modern energy devices to assure a quick and efficient dissection and assist with graspers in the necessary operative steps performed via the anal trocar.

PATIENT SELECTION AND PREPARATION

Patients were recruited from the referred cases to an interdisciplinary center for pelvic floor disorders. Patients with internal and external rectal prolapse were recruited. The protocol was approved by the hospital review board after appropriate preparation. All patients gave informed consent for this new minimally invasive surgical procedure and were older than 18 years of age. Patients were informed by the surgeons in detail and sufficient time was given to allow for reflection and questions.

Extensive preoperative diagnostic work-up was performed in all cases of benign functional disease often associated with rectal prolapse, such as slow transit constipation and pelvic obstruction. All necessary investigations (Hinton test, anorectal manometry, proctologic investigations, rectoscopy, colonoscopy) were performed in our specialized Gastrointestinal and Colorectal Function Laboratory. Dynamic MRI defecography was performed by the Department of Radiology.

The indication in these patients was obstructed defecation due to an internal intussusception of the rectum, often in combination with sigmoid kinking and adhesions, and a full external rectal prolapse. Therefore, a sigmoid resection combined with a rectopexy was indicated in the prolapse patients. Care was taken to extensively evaluate the patients preoperatively for optimal preparation and selection.

The patients underwent a preoperative bowel preparation to have a clean bowel during the operation, since intra-abdominal opening and manipulation of the bowel was necessary. Prior to surgery, prophylactic IV antibiotics (cephalosporin and metronidazole) were given. General anesthesia was performed and the patient was placed in supine position for the operation.

THE TRANSANAL OPERATIVE TECHNIQUE

This hybrid technique uses the natural orifice for instruments and tasks which need a larger diameter of access (>5 mm) to the abdominal cavity, and at the same time allows for laparoscopic assistance via 5 mm ports to avoid access trauma and morbidity.

The traditional laparoscopic rectal resection rectopexy has the following operative steps:¹¹

- Dissection and mobilization of the rectum under preservation of the rectal peritoneal tissue
- Deep mobilization and dissection of the retrovaginal area toward a possible rectocele to lengthen and fully mobilize the scar tissue, which has been developed by the rectal prolapse over years
- Dissection of the redundant sigmoid colon for resection
- Traditional laparoscopic sigmoid resection and circular stapling for descendo-rectostomy
- Pexy of the pararectal peritoneum at the promontorium using non-resorbable suture material and peritoneal adaptation

After establishing a capnoperitoneum via a Veress needle and necessary safety tests, a periumbilical port was introduced into the abdominal cavity. Two additional 5 mm ports were brought into the right lower quadrant for dissection of the colon and rectum. Via these ports instruments for dissection, hemostasis and energy delivery could be used. The dissection of the mesentery was performed stepwise under laparoscopic control to ensure that the pelvic nerve plexus was not in danger and the dissection planes could be followed (Figure 94A.1). In rectal prolapse,



Figure 94A.1 Transanal Endoscopic Applicators (TEAs) in different sizes as transanal trocar with a 3 cm diameter.

it is most important to dissect the rectum distally in the retrovaginal area and free the rectum from all adhesions and scar tissue that have developed over the years. This will allow for an oral mobilization of the rectum toward the promontorium and will also ensure the removal of the prolapse. Time needs to be invested in the careful dissection in this part of the operation to have a high probability for a successful result.

A sigmoidoscopy can be performed to make sure this bowel segment is clean before opening the sigmoid in the abdominal cavity. If it was not completely clean, it could be improved by rinsing the rectum and sigmoid with water. Afterwards, bougies of the sizes 25, 28, and 33 were introduced into the anus and rectum up to the sigmoid colon to widen the proximal rectum. A careful bougienage of the rectum facilitates the following maneuvers.

Then the anvil of a 28 mm circular stapler was introduced into the rectum with a special grasper and maneuvered more proximal up the descending colon to the future anastomotic site (Figure 94A.2). The next step was the transanal introduction of a Transanal Endoscopic Applicator (TEA), which allows for safe introduction of endoscopes, linear staplers, and grasping devices, and specimen removal (Figure 94A.3).¹¹ This was followed by an incision of the colon—usually the distal sigmoid—at the distal anastomotic site. Here, a transanally introduced linear stapler can exit the colon into the abdominal cavity and was used to transect the proximal end of the sigmoid segment, which needs to be resected (Figure 94A.4). At this point, the surgeon manipulates the instruments transanally and transabdominally to coordinate the different surgical steps. With the left hand, he/she uses a grasper to hold the tissue at the descending colon to position the stapler. With the right hand, he/she manipulates the linear stapler, which was introduced into the bowel via the TEA. The TEA itself has a handle, which is held quite flexibly by a second assistant to follow the movements of the surgeon. Via the transanally positioned



Figure 94A.2 In total 3 trocars are used for the ta-CR technique: 1 camera port and 2 working ports (5 mm).

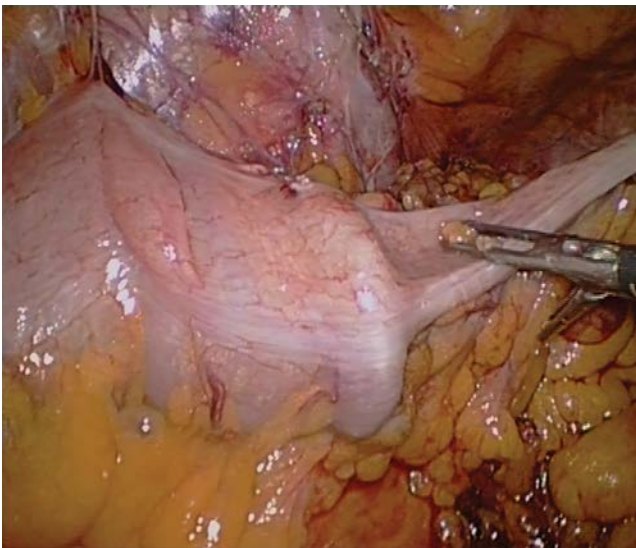


Figure 94A.3 The anvil is positioned intraluminally with a transanal grasper prior to resection at the future proximal anastomotic site.

TEA instrument, the application, removal, and changing of stapling cartridges were technically rather easy to perform. During transection of the colon, care was taken to keep the anvil positioned just proximal from the stapling transection line in order to be there for the proximal anastomosis later.

Once the redundant sigmoid was transected proximally at the descending colon, the proximal colon stump was grasped and opened with scissors at a small spot near the staple line. The intraluminal anvil was grasped through the bowel wall and stabilized. The central pin of the anvil was penetrated through the bowel wall at the small opening at the staple line. Thus, the proximal colon was ready for later anastomosis.



Figure 94A.4 Stapling and division of the colon via the transanal trocar.

Now the distal anastomotic site was completely transected with scissors and/or an energy device. If the bowel still carried some stool, the distal bowel could be closed by another linear stapler via the rectum using the TEA. Once the sigmoid segment was resected and free of detachments, a grasper was advanced via the TEA to reach for the specimen in the abdomen. Then the specimen was pulled through the luminal opening at the distal rectosigmoid stump, via the rectal lumen and via the TEA to the outside.

After removal of the specimen transanally, a purse-string suture was placed at the distal rectosigmoid stump to complete the anastomosis with the circular stapling device. The TEA was removed and a circular stapler was inserted transanally and advanced to the distal rectosigmoid opening, carrying the purse-string suture. The central pin was opened and the purse-string suture was tied down around the central pin. Furthermore, the anvil was connected to the stapler, followed by approximating and firing the device in the usual manner under laparoscopic visual control. Thus, the actual anastomosis could be performed under the same conditions that laparoscopic surgery can provide.

After finishing the anastomosis, a rectopexy was added in the usual technique with non-absorbable sutures between peritoneal, pararectal tissue, and the sacral bone at the promontorium using the 5 mm ports, straight needles, and mini-instruments. After the control of hemostasis, inspection of the anastomosis, and leak test with air and water as well as placement of drainage, the procedure was finished by removal of the three ports.

The patients could drink water and tea on the evening of the operation and were given fluids, including protein drinks, on the first postoperative days. Usually on the third postoperative day, enteral feeding started with soup, semi-solid food and, if they tolerated it well, subsequently also solid food. The initial clinical experience of the past years shows a safe introduction of this NOTES-associated technique into clinical practice.¹¹

DISCUSSION

Laparoscopic operations may require port sizes of 10–15 mm for stapler applications and mini-laparotomies for removal of specimens. This can cause wound problems and hernias in up to 22% of patients.^{12,13} Transanal endoscopic surgery was introduced by Gerhard Buess.¹⁴ With Transanal Endoscopic Microsurgery (TEM) and the specially developed instrument set, an operative endoscope is inserted into the anal canal to the rectum. Through this platform, surgical removal of rectal and distal sigmoid tumors is possible. A more simple transanal system with similar abilities is the TEO (Transanal Endoscopic Operation) system.¹⁵ The latter system can be used with regular laparoscopic instruments. It is quite easy to handle and can be used by any laparoscopic surgeon, since it is similar to working on a mono-port. With the advent of the NOTES concept, we used this TEO port to train on more complex transanal operations such as a sigmoid resection. We decided to use a transanal trocar with a smaller diameter to avoid any possible long-term functional problems.¹¹

Transanal Hybrid-NOTES procedures must be safe; therefore, stepwise transformation from a current laparoscopic procedure with multiple ports and a mini-laparotomy for specimen retrieval to a transanal Hybrid-NOTES procedure with less ports and no incision for the specimen retrieval is necessary. With the introduction of Transanal Hybrid Colon Resections, postoperative long-term anorectal functional problems would be not acceptable.¹⁶ As a consequence, the authors have developed a special TEA with a smaller diameter of 30 mm, from which anorectal functional problems are not to be expected. The diameter of a 33 bougie is most frequently used in colorectal surgery for stapling with absolute minimal side effects regarding functional problems. As a consequence, the authors have chosen a diameter of 30 mm for the TEA to be in a safe range.¹¹ None of the patients developed more severe functional defects especially regarding incontinence postoperatively.

NOTES and Hybrid-NOTES approaches have been reported in the literature in the past years for colorectal surgery.^{17–28} The important idea came from Whitford, Sylla, and Lacy, who reported about their initial experimental work on transanal techniques to operate in the abdomen.^{17–21} Their experience showed that transanal approach to dissect the rectum and further up into the abdominal cavity is quite safely possible. The advantages of the transanal route, with reduced diameter and easy access to the pelvis, and the advantages of laparoscopy, with excellent overview using transabdominal camera position, are combinedly used in clinical practice with the hybrid technique.¹¹ This allows for excellent maneuverability and triangulation from 3 and 5 mm graspers, good exposure for 5 mm energy devices, and a safe handling of the tissue. Morbidity of 5 mm ports is minimal and that of 3 mm ports is negligible. If the transanal orifice approach can be used for all tools with a diameter greater than 5 mm and the actual opening in the bowel for transanal intra-abdominal access can be later used for anastomosis, an ideal solution

can be reached. The possible benefits of this Hybrid-NOTES technique compared to traditional laparoscopic colectomies are less wound infection problems, less hernia frequency, and possible quicker recovery for daily activities.^{22–28} This has to be proved in comparative studies.

CONCLUSIONS

Transanal hybrid colon resection seems, from this initial experience, a feasible and safe method of Hybrid-NOTES procedure, which has been introduced into clinical practice. The good quality of laparoscopic overview, the delivery of energy for safe dissection, and the advantages of instrument triangulation can be used. In addition, abdominal access trauma is limited to maximum 5 mm ports with low probability of subsequent morbidity by using the advantage of a natural orifice via the transanal route for all other manipulations requiring an access larger than 5 mm such as staplers, endoscopes, and specimen retrieval.

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Laparoscopic transabdominal preperitoneal inguinal hernia repair

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INTRODUCTION

Inguinal hernias remain one of the most common problems that present to the general surgeon. There are many ways to approach them, from observation to a variety of surgical repairs. Currently, the tension-free open repair with mesh and laparoscopic repair are considered to be of equal efficacy and results. Of the laparoscopic repairs, the two most commonly used are the total extraperitoneal (TEP) and the transabdominal preperitoneal (TAPP) techniques. Each has its own advantages and disadvantages, and the comparison of the two is beyond the scope of this chapter. The choice between the two procedures remains surgeon preference.

The TAPP repair does offer surgeon and patient advantages that make it preferable in certain clinical scenarios, and in many surgeons' hands, it is the go-to choice for primary inguinal hernias. The technical steps, as well as the indications and complications of TAPP, as well as the supporting evidence, are discussed in this chapter.

TECHNICAL ASPECTS

A TAPP repair is similar to a TEP repair in the important steps of identifying hernia defects, reducing hernia contents and sac, and mesh placement. Where they differ is access to the preperitoneal space, and for the TAPP, closure of the peritoneal flap. There is variation in how the procedure is done and little to no evidence for strict guidelines on how the surgery should be performed. However, there are basic principles that the International Endohernia Society (IEHS) recommends¹:

Step 1. The peritoneal cavity is accessed and insufflated. This can be done with open Hasson technique, Veress needle, direct trocar insertion, or visual entry (with or

without previous gas insufflation). Once the abdomen is insufflated, two more 5 mm trocars are introduced laterally under direct vision on each side of the abdomen, just below the level of the infraumbilical trocar ([Figure 95.1](#)).

Step 2. If there is an incarcerated inguinal hernia, the contents are gently reduced. If there are adhesions of omentum or intestine locally to the peritoneum, adhesiolysis does not need to be performed unless the adhesions interfere with the ensuing operation.¹



Figure 95.1 Introduction of two more 5 mm trocars laterally under direct vision on each side of the abdomen, just below the level of the infraumbilical trocar.



Figure 95.2 Internal inguinal ring.

Step 3. A peritoneal flap is created to enter the preperitoneal space surrounding the spermatic cord. Electrocautery using the hook dissector or laparoscopic scissors can be used to score the peritoneum and enter the preperitoneal space starting about 3–4 cm superior to the internal inguinal ring (**Figure 95.2**). This flap is then extended medially to the level of the median umbilical ligament and laterally to the level of the anterior superior iliac spine. It is extended inferiorly through the avascular areolar tissue to about 2–3 cm inferior to Cooper ligament, at the level of the superior arch of the pubic bone. The full extent of the pelvic floor should be dissected to ensure no occult direct or femoral hernias are present. Adequate space should be made to place a 10 × 15 cm piece of mesh (**Figure 95.3**).

Step 4. The pubic symphysis is identified, and the adherent areolar tissue is cleaned off between the symphysis and the pubic tubercle and Cooper ligament. At this time, the adipose tissue against the undersurface of the transversalis fascia of the direct space can begin to be cleaned off to assure there is no direct hernia.

Step 5. The dissection should be carried out laterally, with the dissection of the areolar connective tissue between the peritoneal flap and the transversalis muscle fibers at the level of the anterior superior iliac spine. Once this lateral space is created, the peritoneal edge can be followed medially until it meets the cord elements in a male (or round ligament in a female) and an indirect hernia can be ruled in or out.

Step 6. The adherent tissue to the spermatic cord is dissected off of the medial and lateral aspects of the hernia sac. Identification and preservation of the cord elements are key. Begin with the lateral surface by pulling the peritoneal sac medially, teasing the tissue off of the peritoneum. While doing this, the vascular supply and the vas

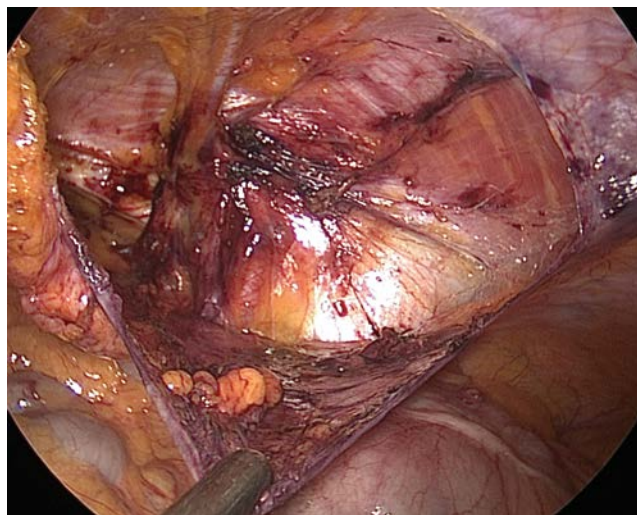


Figure 95.3 Adequate space should be made to place a 10 × 15 cm piece of mesh.

deferens can be identified and preserved. To perform the medial dissection, the peritoneal sac can be pulled laterally and anteriorly. Understanding the precise location of the iliac vein is important during this dissection.

Step 7. The peritoneal edge of the hernia sac is reduced off of the cord completely and down to a level below the iliac vessels. The advantage of the peritoneal flap created for the TAPP at this stage is that it allows you to appreciate the reduction of the hernia sac more easily from within the peritoneal cavity. In exceptional cases with a very large and chronically incarcerated hernia sac, the sac can be transected at the level of the internal inguinal ring to prevent injury to the cord structures. An attempt should be made to close the peritoneum on the proximal end (with an Endoloop, Endoclips, or suture), if possible, but you can leave the end within the canal open and patent.

Step 8. Look for and reduce and/or excise any cord or preperitoneal lipomas. IEHS recommends reducing and excising any cord lipomas or preperitoneal lipomas in the direct or femoral spaces, as these are a common cause of “recurrent” hernias.

Step 9. A “critical view” is obtained before inserting the mesh, simply assuring a completely dissected myofascial orifice where you can see the symphysis in the midline, Cooper ligament, and the femoral and direct space. You should also see the cord elements without any remaining tissue medially, the completely cleared internal ring, and the edge of peritoneum and hernia sac clearly reduced below the level of the iliac vessels.

Step 10. Mesh insertion. The mesh should measure a minimum of 10 × 15 cm. It is OK for the corners to be rounded or preshaped. For a larger hernia, a larger mesh can be used. The decisions of what mesh to use (lightweight versus heavyweight, large pore versus small pore, etc.), and what fixation material to use if any (no

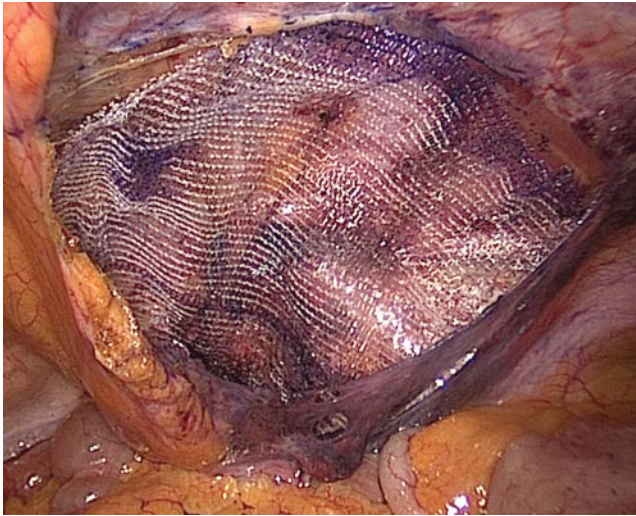


Figure 95.4 The surgeon should assure that the mesh crosses the midline medially, and that inferiorly there is enough peritoneum dissected below the level of the iliac vessels.

fixation, permanent tacks, absorbable tacks, or fibrin glue) are beyond the scope of this chapter and remain surgeon preference. However, for TAPP, with a hernia defect larger than 4 cm, the IEHS recommends fixating the mesh. The mesh should lay flat and should not fold upon itself. The surgeon should assure that the mesh crosses the midline medially, and that inferiorly there is enough peritoneum dissected below the level of the iliac vessels. This will avoid hernia recurrence under the mesh (**Figure 95.4**).

Step 11. Once the mesh is in place, the peritoneal flap needs to be closed and reapproximated. This can be done using staples, tacks, running suture, or fibrin glue. There is no evidence to show superiority of one method. The important aspect of this step is to ensure the peritoneum is completely closed in order to avoid contact of bowel with mesh. If there is difficulty in reapproximating the peritoneal edges, the insufflation should be decreased to as low as possible, still providing enough domain to comfortably work (**Figure 95.5**).

Step 12. Finally, after assuring hemostasis and no injuries to peritoneal structures (particularly bowel and mesentery), the infraumbilical fascia should be closed.

SPECIAL APPLICATIONS FOR TAPP APPROACH

Incarcerated and strangulated hernias

A TAPP is particularly advantageous in managing an incarcerated or strangulated inguinal hernia. By performing a TAPP repair in these scenarios, the surgeon can evaluate the bowel properly and can even spare the patient a bowel resection more often than with an open repair. The bowel can be

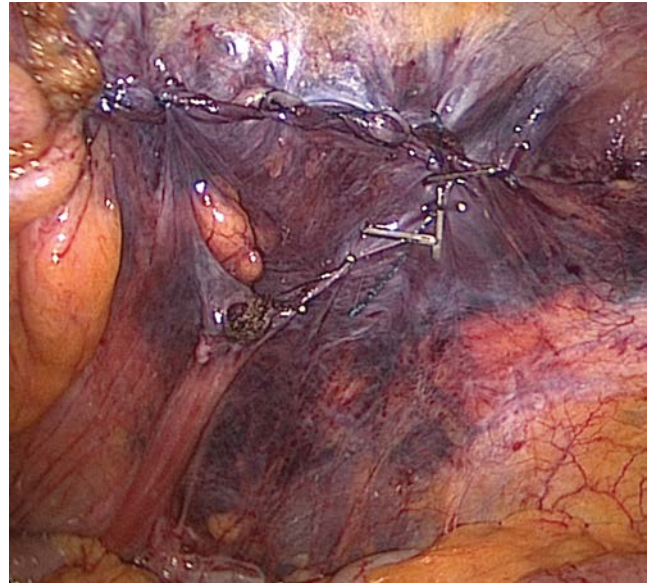


Figure 95.5 Once the mesh is in place, the peritoneal flap needs to be closed and reapproximated.

reduced, and while the hernia is being repaired, adequate time passes to observe if the bowel is viable or not. If the segment of bowel remains ischemic, it should be resected, and the IEHS recommends extracorporeal resection and anastomosis. The use of mesh after finding a true strangulation or bowel ischemia remains at the discretion of the surgeon, though employing a permanent synthetic material in a clean-contaminated or contaminated field carries a risk of chronic mesh infection and is therefore best avoided. An absorbable material is probably the safest choice if the field is clean-contaminated. If the field is contaminated, then it is best to stage the repair or perform a primary tissue repair without mesh.

Scrotal hernias and large hernia sacs

Inguinal scrotal hernias are probably more common than typical reporting might indicate. Small scrotal hernias that are reducible can be approached initially via the TEP procedure. But the larger, incarcerated, or chronic scrotal hernias, especially those with large-diameter necks, are sometimes better approached using a TAPP or open technique. A TAPP repair provides a great view of the incarcerated contents, and it usually allows for a straightforward reduction.

To reduce the volume of hernia sac in the canal, the retained sac can be pulled intrapreperitoneally and tacked to the lateral edge to the anterior abdominal wall. This can decrease the incidence and size of seroma formation. Patients with these types of hernias should be warned about seromas, as they are fairly common. In these large hernias, a partial hernia sac can be left *in situ* in the scrotum if it is not possible to safely reduce it.

Recurrent hernias

For experienced laparoscopists, a recurrence after a previous TEP or TAPP approach demands a TAPP. Some surgeons will always resort to an open anterior approach for a patient with a recurrence. During the laparoscopic dissection, if an additional open incision will help with mesh removal or cord preservation, it may be added to at this point. Debating which procedure is best to perform after a recurrence has been extensively evaluated in the literature and is beyond the scope of this chapter, but it is clearly dependent on surgeon experience. For recurrences, the IEHS recommends TAPP, if feasible.

Patients with previous Pfannenstiel or lower midline incisions

Some patients with previous Pfannenstiel or lower midline incisions will not have a peritoneal layer and thus are not candidates for a TEP repair. In such situations, a TAPP is the only laparoscopic repair possible. In addition, some Pfannenstiel incisional hernias will feel on palpation like inguinal hernias, when the defect is, in fact, midline. A preoperative computed tomography scan can help differentiate between the two. Using a laparoscopic approach allows for an accurate diagnosis and repair concomitantly. Of note, a history of prostatectomy carries a small but not insignificant risk of bladder injury, and dissection should proceed cautiously in that region.

COMPLICATIONS AFTER TAPP APPROACH

Inguinodynia

Pain following a hernia repair is less commonly reported after laparoscopic hernia repair compared to open repair. Generally, pain after an inguinal hernia repair is caused by the material inserted (mesh, tacks, or sutures), an inadequately reduced hernia, or a missed lipoma or hernia. The pain resulting from inserted mesh, fixation tacks, or sutures can be caused by direct irritation from the material, or by adjacent nerve damage. In a laparoscopic repair, the nerves at risk are the lateral femoral cutaneous nerve, the genital branch of the genital femoral nerve, the ilioinguinal nerve, and the iliohypogastric nerves. To avoid neuropathic pain from a TAPP, if mesh is fixated, no tacks or sutures should be placed laterally below the level of the anterior superior iliac spine.

Seroma formation in large defects

Large cavernous defects, both direct and indirect, run the risk of forming large seromas. While these are self-limited, they can last many months and be uncomfortable for patients. One way to minimize these from forming is to take

the redundant attenuated transversalis fascia, pull it into the preperitoneal space, and fixate it to Cooper ligament with a permanent tack.

Small bowel obstruction

Small bowel obstruction is possible, though very rare. It can occur from a loop of bowel herniating through a defect in the peritoneum, or adhering to the peritoneal closure fixation material. Patients who present with nausea and vomiting in the postoperative period should be aggressively evaluated to rule out this entity.

Urinary retention

TEP and TAPP have a higher incidence of urinary retention than an open repair done under local anesthesia with sedation. This is likely due to the necessity of general anesthesia for laparoscopy. IEHS recommends fluid restriction (less than 500 cc intravenous fluids) during the operation to reduce the risk of urinary retention.

Port-site hernias

As the TAPP repair violates the peritoneal cavity, it is no surprise that more port-site hernias occur with this repair as compared to the TEP. Adequate fascial closure of all trocar sites larger than 5 mm should be done to prevent this complication.

Visceral injuries

Additionally with TAPP, visceral injury is more common than with TEP or an open repair, although it is still uncommon.

DISCUSSION

Overall, there is no evidence showing superiority of TAPP versus TEP, but there are some small differences. A meta-analysis of a hernia database including over 17,000 patients found that the postoperative complication rate for TAPP versus TEP repair was slightly higher. However, this was determined to have an association with the higher rate of large hernia defects and scrotal inguinal hernias that were repaired using TAPP.²

Additionally, one prospective randomized study of almost 300 patients found that TAPP was associated with longer operative time and higher incidence of early postoperative pain compared to TEP, but TEP was associated with more seroma formation. Overall, long-term outcomes were comparable between the two.³

Finally, a Cochrane review of TEP versus TAPP determined that TAPP is associated with higher rates of port-site hernias and visceral injuries; however, there were more conversions to open repair with TEP. Importantly, it found no economic difference between the two. The intraoperative and general postoperative complication rates, as well as reoperation rates, were similar for the TEP and TAPP repairs.⁴

CONCLUSION

A TAPP technique offers solutions to the complex and common problem of repair of inguinal hernias. It has similar

efficacy and complication rates as the TEP repair. In a skilled laparoscopic surgeon's hands comfortable with this technique, the TAPP offers a unique skill set for approaching specific complications of inguinal hernias.

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Laparoscopic component separation

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INTRODUCTION

Incisional hernia complicates approximately 10%–20% of planned laparotomies and up to 35% of emergency procedures.¹ The optimal technique of ventral incisional hernia repair has evolved over time from primary suture repair with attendant risk of recurrent hernia to repairs incorporating reinforcing mesh. Fascial approximation with recreation of the linea alba and mesh reinforcement has been shown to be superior to suture repair.^{2–4} Hernias whose size precludes full medialization of the rectus muscles present a challenge to surgeons. Other difficult scenarios include closure of a long-term open abdomen following trauma or abdominal catastrophe, and the management of a hernia defect after excision of infected mesh used in a previous ventral hernia repair.

In 1990, Ramirez, Ruas, and Dellon presented a case series of patients treated for massive incisional hernias with a new technique presented as the “components separation method.”⁵ The described components are the layers of the abdominal wall, which were further investigated in the paper with a cadaveric study. As classically described, the medial borders of the rectus musculature were brought together in the setting of a massive hernia by dividing the external oblique aponeurosis (EOA) and reflecting the external oblique muscles laterally so that these lateral-anchoring muscles would allow medialization of the rectus. As described by Ramirez et al.,⁵ 10 cm of rectus medialization was accomplished by unilateral division of the EOA; therefore, with bilateral EOA component separation, a defect 20 cm in size could be closed primarily by suturing the medial borders of the rectus to recreate the linea alba. The authors, plastic surgeons by training, advocated for this technique in large ventral hernias to obviate the need for pedicled flaps of fascia and muscle from other sites that were used to patch the residual defect when full apposition of the rectus muscles was not possible during conventional repair of giant ventral hernias (Figure 96.1).

This technique began with a midline incision and adhesiolysis to free intestinal adhesions from the fascial edge. In order to access the linea semilunaris to perform component separation, lipocutaneous flaps were raised with electrosurgical devices. Dissection was continued laterally until the linea semilunaris and an additional 2–3 cm of external oblique muscle were exposed prior to division of the EOA. This initial report includes division of neurovascular bundles that supply the lipocutaneous flaps; this creates a large dead space between the anterior abdominal wall musculature and the overlying complex of adipose tissue and skin.

Though the initial report and case series of 11 patients published by Ramirez et al.⁵ reported no wound-related complications, subsequent case series using the open components separation (OCS) technique described by these authors reported wound complications of up to 62%.^{6–9} Variation in hernia size,^{5–8} mesh utilization,^{10–13} definitions of severity of wound complications, and length of follow-up between case series complicate the formation of definite conclusions, but an accepted wound complication rate of approximately 30% led to some surgeon reticence to incorporate the components separation technique as described by Ramirez et al. into clinical practice for massive hernias.

The major morbidity of anterior component separation incorporating EOA division is wound-related morbidity due to the extensive lipocutaneous undermining and dead space creation required to access the EOA. Though “perforator”-preserving (or vessel-preserving) techniques are described, raising the lateral lipocutaneous flaps compromises the vascular supply to the overlying adipose tissue and skin while simultaneously leaving the resulting dead space in communication with the incision used to repair the hernia defect. Though subcutaneous drains are routinely employed to drain the dead space created by this dissection, the series listed describes a high rate of wound-related complications ranging from cellulitis to wound breakdown requiring operative debridement and revision. These high levels of

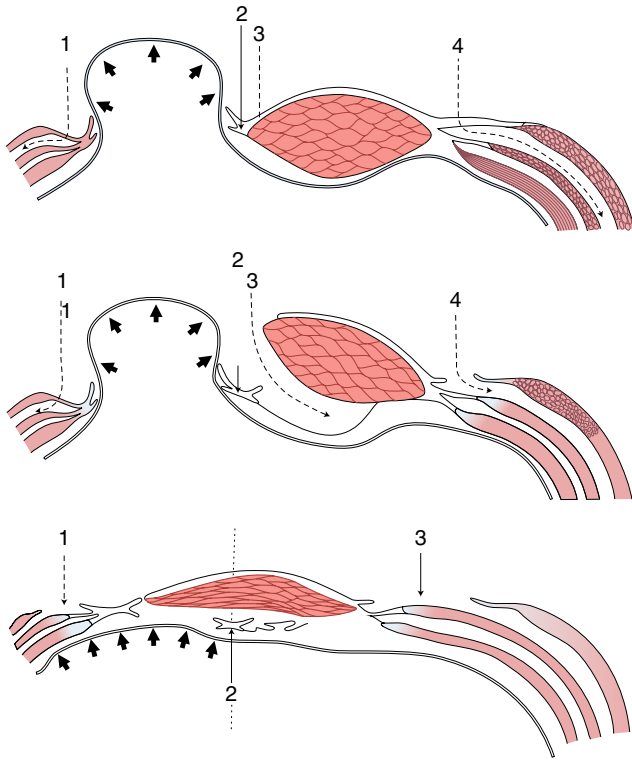


Figure 96.1 A cross-sectional representation of the muscular and fascial layers of the abdominal wall provided in Ramirez et al.'s 1990 description of open components separation. The external oblique aponeurosis is divided and the external oblique muscle reflected laterally to facilitate medialization of the rectus abdominis (RA) muscle for coverage of the midline hernia defect. (Reprinted with permission from Ramirez OM et al. *Plast Reconstr Surg* 1990;86[3]:519–26.)

wound-related complications also resulted in reticence to place synthetic mesh for hernia reinforcement. Some early series describing component separation hernia repairs utilized expanded polytetrafluoroethylene (ePTFE) mesh with high rates of infection requiring mesh excision¹⁴; this further limited the widespread use of mesh in early series until biologic or semisynthetic materials became more extensively developed and widely available.

In addition to optimizing operative sterility practices and patient-related factors, such as eliminating tobacco use prior to elective component separation hernia repairs, two additional techniques were developed to combat the wound-related morbidity associated with component separation: posterior component separation (PCS) and laparoscopic component separation (LCS). In 2000, Lowe et al. presented the first description of laparoscopic anterior component separation.¹⁵ Acknowledging the wound-related morbidity of open external oblique release, this group hypothesized that a percutaneous laparoscopic-assisted technique would minimize vascular soft tissue damage with resulting flap hypoperfusion and would result in fewer wound complications, decreased pain, and improved cosmesis, which would

result in a shorter length of stay. In a series comparing seven hernias repaired by LCS with thirty repaired via the open technique, Lowe et al. described a laparoscopically assisted percutaneous method for accessing and dividing the EOA.¹⁵ This technique utilizes expanding dissection balloons to expose the anterior abdominal wall and represents a laparoscopic-assisted version of the OCS technique in which the anterior surface of the EOA is directly visualized and divided. This technique was subsequently modified by Maas in 2001¹⁶ and later by Rosen in 2007¹⁷ to incorporate dissection between the external and internal oblique muscles. Here, the dissection balloon is placed between layers of the abdominal wall so that external oblique release is performed by dividing the posterior surface of the EOA rather than by addressing its anterior surface as described by Ramirez et al.⁵ and Lowe et al.¹⁵

LAPAROSCOPIC COMPONENT SEPARATION TECHNIQUE: ANTERIOR APPROACH (LOWE)

With the patient in the supine position, a midline laparotomy is performed and the hernia reduced. The hernia sac is excised. Adhesions of bowel to the posterior abdominal wall and midline fascia are divided. To perform LCS, the locations of the inferior costal margin, 11th rib, and anterior superior iliac spine (ASIS) serve as palpable landmarks. A small incision is made 5 cm medial to the ASIS, and blunt dissection is used to expose the anterior abdominal wall at the expected location of the linea semilunaris. A laparoscopic dissector balloon is placed into this incision and inflated to create a space superficial to the anterior abdominal wall. Once the space is created to the level of the inferior costal margin, a second incision is made 2 cm caudal to the inferior costal margin inline with the ipsilateral lower abdominal incision. A trocar is placed in this location, and a second trocar is placed 3 cm superior and medial to the first laparoscopic incision. The dissection exposes the EOA, and the muscle is divided progressively until it has been released from the costal margin to the level of the ASIS. The muscle is then retracted laterally; this typically requires blunt mobilization to facilitate lateral reflection of the external oblique muscle. Prior to completing the midline fascial reapproximation, closed suction drains are left in the developed space (**Figures 96.2 and 96.3**).

LAPAROSCOPIC COMPONENT SEPARATION TECHNIQUE: INTERMUSCULAR APPROACH (MAAS/ROSEN)

After entering the abdomen through a midline laparotomy, resecting the hernia sac, and dividing adhesions to the posterior abdominal wall and midline fascia, palpation along the unilateral rectus muscles from the abdominal incision identifies their lateral border. A 2 cm transverse incision

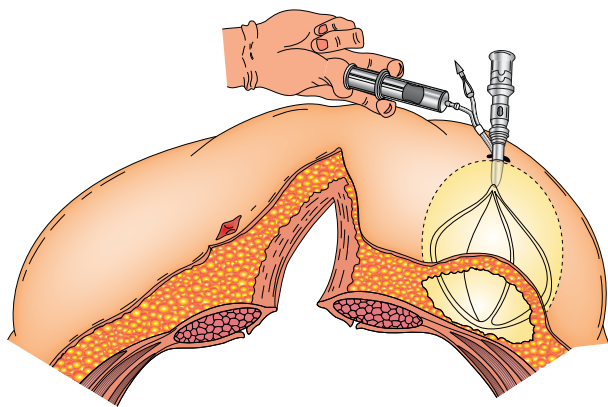


Figure 96.2 As described originally by Lowe et al.,¹⁵ an inguinal hernia balloon dissector is placed superficial to the anterior abdominal wall and expended to create a space whose inferior surface is the abdominal wall at the level of the linea semilunaris; the superior and lateral borders are adipose tissue. (Reprinted with permission from Lowe JB et al. *Plast Reconstr Surg* 2000;105[2]:720–9; quiz 30.)

is made at the expected site of the midpoint of the linea semilunaris and is carried down through the subcutaneous tissues until the EOA is identified. The aponeurosis is elevated, and an incision in the EOA is made lateral to its insertion along the lateral edge of the anterior rectus sheath. The internal oblique muscle is reflected posteriorly, and the dissecting balloon is introduced and inflated. As described

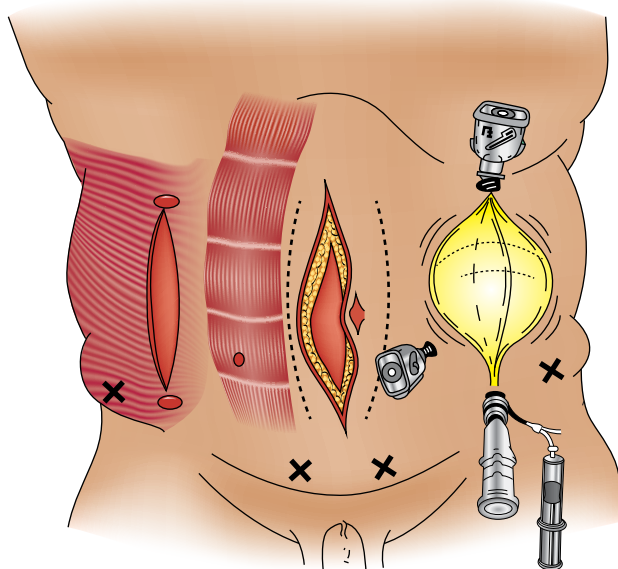


Figure 96.3 Once the space is created anterior to the abdominal wall, additional trocars are placed for retracting/dissection instruments and an energy device or shears to divide the EOA. (Reprinted with permission from Lowe JB et al. *Plast Reconstr Surg* 2000;105[2]:720–9; quiz 30.)

by Maas et al.,¹⁶ the balloon is removed and the EOA is elevated with retractors; a 30° laparoscope is then inserted into the plane developed between the oblique muscles. Division of the EOA is performed from the pubic symphysis to the inferior costal margin via instruments inserted through the single skin incision previously utilized for introduction of the balloon dissector.

As described by Rosen et al.,¹⁷ a two- to three-trocar approach is utilized for component separation. A 1–2 cm incision is made lateral to the lateral border of the rectus muscles 2–3 cm caudal to the inferior costal margin, and dissection through the subcutaneous tissues exposes the EOA. The EOA is elevated between clamps and incised in the superolateral to inferomedial direction of the fibers of the EOA. The internal oblique muscle is then visualized, and an expanding balloon dissector is introduced between the EOA and the internal oblique muscle; a small amount of blunt dissection may be required to create a pocket for initial balloon placement. The space is created by insufflating the balloon toward the inguinal region. Confirmation of the correct location of dissection is accomplished by analyzing the orientation of the muscle fibers forming the anterior and posterior confines of the created space. The anterior wall is composed of the external oblique muscle with inferomedial fibers, while the posterior wall should have superomedially oriented fibers of the internal oblique muscle.

The balloon dissector is then replaced by a balloon-tipped trocar, through which the expanded space is maintained via pneumoinsufflation to 12–14 mm Hg. Additional dissection of this intermuscular plane is carried out bluntly as needed with a 30° laparoscope to expose the areas in which the working ports are inserted. Two 5 mm working ports are then placed under laparoscopic visualization for retraction and division of the EOA. The first is placed at the level of the umbilicus in the posterior axillary line; an alternative location for this port is one-third of the distance from the costal margin to the ASIS but also in the posterior axillary line.¹⁸ The second trocar is placed lateral to the rectus sheath cephalad to the inguinal ligament. Under laparoscopic visualization via the superior port, the intermuscular plane is fully developed from the external oblique muscle insertions on the lower ribs to the pubic symphysis and medial inguinal ligament. Full exposure of the intermuscular space will reveal the lateral rectus sheath as the medial extent of the space and will continue laterally to the posterior axillary line (Figure 96.4).

Under laparoscopic visualization, the external oblique muscle release is performed as described by Rosen¹⁷ with laparoscopic shears coupled with cautery; alternatively, an ultrasonic dissector may be employed. The energy device is deployed through the medial incision, and dissection is visualized through either the superior or inferior incision. Changing laparoscope location may be required to visualize the cephalad or caudal extents of the dissection. The incision is made at the junction of the external oblique muscle and aponeurosis and performed from the superior insertions of the EOA along the inferior ribs to the pubic

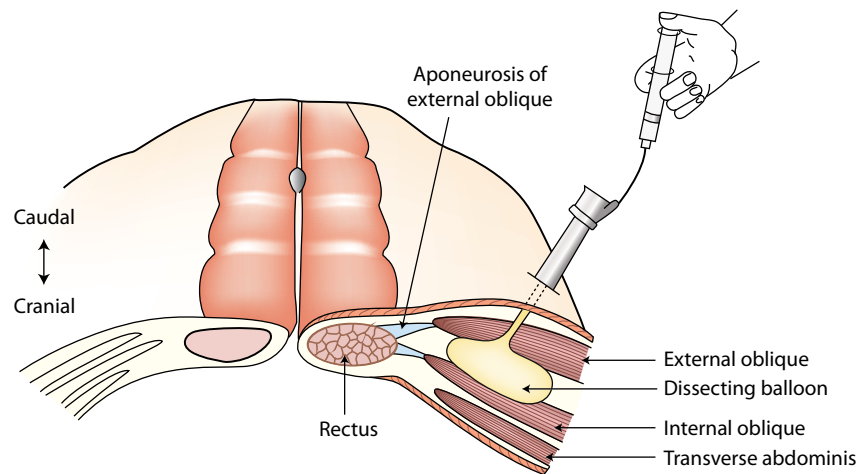


Figure 96.4 Interoblique balloon dissection technique described by Rosen et al.¹⁷ The space is directly accessed by incising the external oblique aponeurosis. The dissection balloon is inserted and serially inflated and desufflated, progressing from the initial subcostal incision toward the inguinal ligament. (Reprinted with permission from Rosen MJ et al. *Hernia* 2007;11[5]:435–40.)

symphysis. Once full fascial release has been accomplished and the space has been inspected for hemostasis, a closed suction drain is introduced into the space and the cutaneous incisions are closed. The technique is repeated on the contralateral side for maximal rectus medialization (**Figure 96.5**).

An alternative technique combining the approach of Rosen et al.¹⁷ with that of Clarke¹⁹ is utilized in our

institution. This begins with a 2 cm incision and dissection to the EOA at the inferior costal margin and insertion of a balloon dissector deep to the EOA. The balloon is then sequentially inflated, deflated, and advanced, progressing caudally to develop the intermuscular space. Once the space is developed to the level of the inguinal ligament, the balloon dissector is removed, and a narrow “S” retractor is used to elevate the EOA. A 5 mm 30° laparoscope is introduced

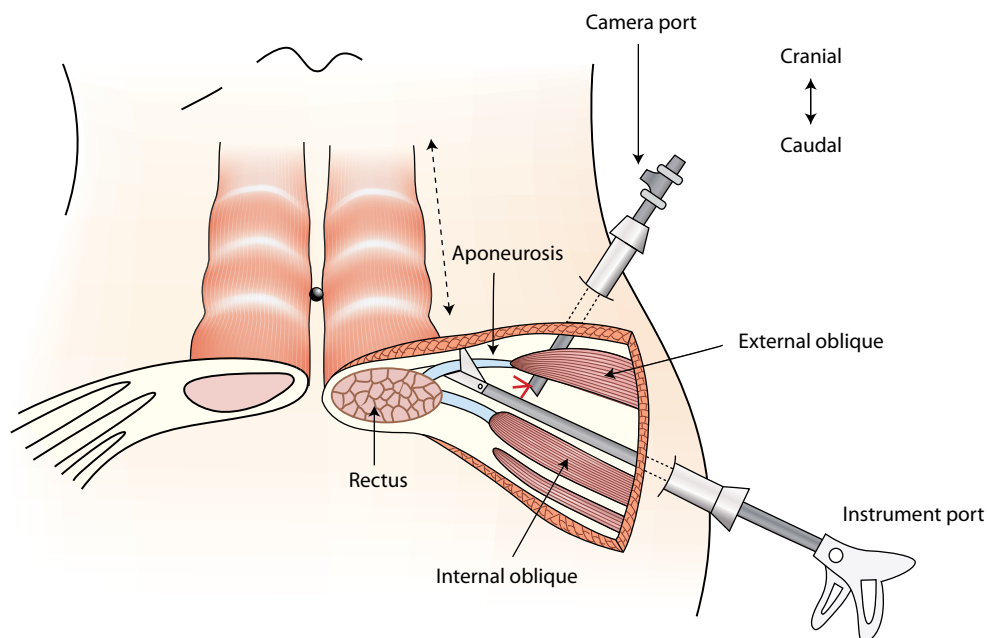


Figure 96.5 After developing the interoblique space, the balloon dissector is replaced with a balloon trocar. Additional ports are placed for retraction and scissors or an energy device are used to divide the external oblique aponeurosis. Dividing attachments on the lower costal margin and pubis may require instrument and camera exchange between trocars. (Reprinted with permission from Rosen MJ et al. *Hernia* 2007;11[5]:435–40.)

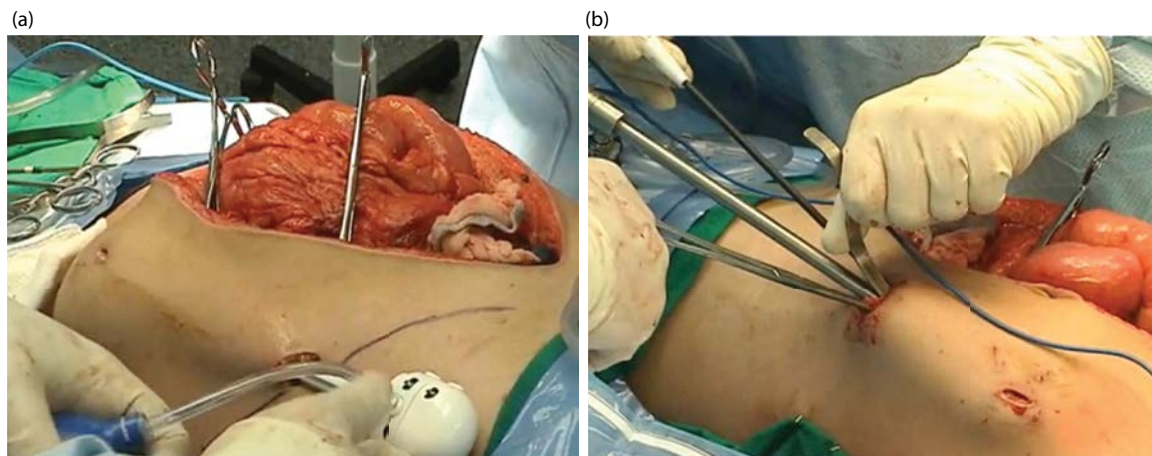


Figure 96.6 (a) A 2 cm incision is made 2–3 cm caudal to the inferior costal margin in the midclavicular line at the expected location of the edge of rectus. This is confirmed by palpating the lateral extent of the rectus muscle from the midline incision. A balloon dissector is inserted into the intermuscular space and sequentially inflated, deflated, and advanced caudally to separate the external and internal oblique muscles. (b) The orientation of the laparoscope and instruments used to perform external oblique release.

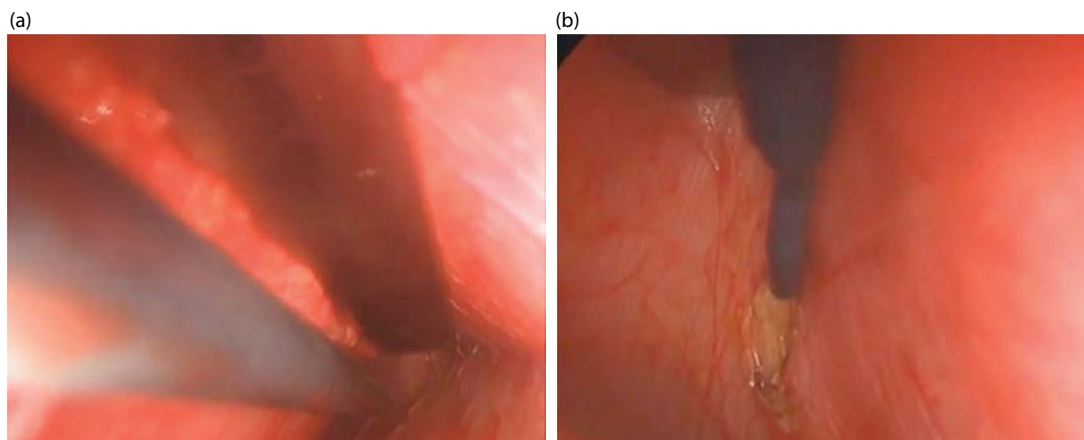


Figure 96.7 (a) Laparoscopic appearance of the intermuscular space. The edge of rectus is seen as the right lateral border of the space, while the internal oblique muscle is seen inferiorly. The external oblique aponeurosis is seen as the superior border of the space. (b) Division of the external oblique aponeurosis exposes the adipose tissue between the aponeurosis and the abdominal skin.

into the space, and the EOA is visualized as the “roof” of the space. A laparoscopic hook electrocautery device is introduced into the space, and the EOA is progressively divided from the inguinal ligament to the inferior costal margin as the laparoscope and cautery device are withdrawn from the inguinal region toward the incision at the inferior costal margin. The intermuscular space is not insufflated in this technique. This avoids the routine use of a balloon port and additional flank or lower abdominal incisions and trocars, and may compare favorably in terms of procedure cost (**Figures 96.6 and 96.7**).

While this minimally invasive, two-incision laparoscopic component separation may be performed to aid with closure of an open abdomen, it could also be used in elective repair

of a ventral hernia. Combining this measure with laparoscopic ventral hernia repair allows for primary fascial closure prior to mesh placement.

OPEN VERSUS LAPAROSCOPIC COMPONENT SEPARATION: COMPARISON OF OUTCOMES

Given a historical wound morbidity rate ranging from 20% to 62%,^{6–8,10,11,20} development of a minimally invasive component separation technique as outlined has focused on differences in wound complications, such as wound infection, seroma formation, skin necrosis, and wound dehiscence. Hernia recurrence, ranging from 8% to 32%

in open series,^{6,11} has also been examined along with hospital length of stay.

Though animal models comparing laparoscopic and open anterior component separation suggest that laparoscopic release of the external oblique muscle achieves approximately 86% of the myofascial advance obtained through open release,²¹ initial studies such as that by Lowe¹⁵ comparing open and endoscopic component separation identified no difficulty in obtaining rectus medialization and defect coverage with a median defect size of 315 cm². Variations in hernia defect size, use and type of mesh reinforcement, length of postoperative follow-up, and inclusion of an institutional open component separation arm are reported in series detailing outcomes after laparoscopic component separation. The definitions of major wound complications also vary between studies. While Lowe's initial case series reporting the anterior approach to laparoscopic component separation reported no wound complications and a hernia recurrence rate of 14%,¹⁵ the intermuscular approach described by Rosen et al. reported a wound complication rate of 29%.¹⁷ Notably, Rosen's 2007 study was performed for the treatment of recurrent hernias with active infection requiring mesh excision; no recurrences were noted in this series with a short follow-up period. The institutional experience with open and laparoscopic anterior component separation reported by Harth in 2010²² and subsequently in 2011²³ demonstrates decreased wound complication rates (27% LCS versus 50% OCS in 2010; 28% LCS versus 46% OCS in 2011). Hernia

recurrence reported in the earlier Harth study was similar between arms (27% LCS versus 27% OCS).²²

Decreased wound-related morbidity was reinforced by Giurgius et al. in a case series comparison of the two techniques with a resulting significant decrease in wound-related morbidity (19% LCS versus 57% OCS, $p = 0.03$); a single hernia recurrence in the LCS group (5%) and no recurrence in the open cohort ($p = \text{NS}$) were reported.²⁴ In 2013, Fox et al.²⁵ also reported a decreased wound-related morbidity in their retrospective series comparing 18 LCS with 26 OCS procedures. The wound complication rate was decreased in the LCS group compared with the OCS group (6% LCS versus 27% OCS, $p = \text{NS}$) with an accompanying decrease in hernia recurrence rate (17% LCS versus 27% OCS, $p = \text{NS}$).²⁵ Similar results were reported by Albright et al. and Ghali et al., who found decreased wound complications in the laparoscopic group.^{26,27} In Albright's series, surgical intervention for wound complications was performed exclusively in the OCS group. Given lower rates of wound morbidity and infection with the endoscopic technique, several authors recommend this approach for thick abdominal walls with expected lipocutaneous ischemia should OCS be performed,²² in the case of infected mesh in the midline with or without recurrent hernia,^{17,26} or for multiple recurrent ventral hernias with no history of components separation. The size of the hernia defect must also be considered during operative planning, as full mobilization with OCS may be required for defects approaching 20 cm in size (Table 96.1).

Table 96.1 Summary of population and outcomes of referenced series of hernia repairs completed with the component separation technique

Author	Population	Wound morbidity, Number (%)	Hernia recurrence, Number (%)	Defect size, median, cm ²
Ramirez et al. ⁵	11 OCS	0	0	216
Lowe et al. ¹⁵	7 LCS	0	1 (14)	315
Giroto et al. ¹⁰	96 OCS with onlay mesh	25 (26)	21 (22)	140
de Vries Reilingh et al. ⁶	43 OCS	14 (33)	12 (28)	234
Borud et al. ⁷	12 OCS	6 (50)	1 (8)	10–15 cm wide
Rosen et al. ¹⁷	7 LCS	2 (29)	0 (0)	338
Ko et al. ⁸	200 OCS	86 (43)	43 (22)	–
Harth and Rosen ²²	22 OCS	OCS: 11 (50)	OCS: 6 (27)	392 OCS
	22 LCS	LCS: 6 (27)	LCS: 6 (27)	324 LCS
Harth et al. ²³	22 OCS	OCS: 10 (46)	–	–
	32 LCS	LCS: 9 (28)	–	–
Giurgius et al. ²⁴	14 OCS	OCS: 8 (57)	OCS: 0 (0)	–
	21 LCS	LCS: 4 (19)	LCS: 1 (5)	–
Ghali et al. ²⁷	50 OCS	OCS: 16 (32)	OCS: 4 (8)	273.8 ± 193.6 ^a
	57 LCS	LCS: 8 (14)	LCS: 2 (4)	405.4 ± 186.8 ^a
Fox et al. ²⁵	26 OCS	OCS: 7 (27)	OCS: 7 (27)	–
	18 LCS	LCS: 1 (6)	LCS: 3 (17)	–
Singh et al. ¹¹	58 OCS with onlay mesh	19 (33)	4 (7)	–
Klima et al. ¹²	74 OCS with preperitoneal mesh	10 (14)	3 (4)	299 ± 161

Abbreviations: LCS, laparoscopic component separation; OCS, open component separation.

^a Defect size reported as mean ± standard deviation.

OPEN VERSUS LAPAROSCOPIC COMPONENT SEPARATION: COMPARISON OF QUALITY OF LIFE

Large ventral hernias can cause pain, physical limitation, and psychosocial difficulties for patients; the size of giant ventral hernias or patient comorbidities such as diabetes, tobacco use, previous infection, or previous failed repairs may make surgeons reluctant to pursue elective repair. Hernia size and history of recurrence, however, are two factors that influence the choice of component separation when repair is undertaken. Compared with bridging mesh techniques, recreation of the musculofascial abdominal wall via primary fascial approximation improves the function of the abdominal wall and decreases hernia recurrence.^{9,10,28} Though wound complications and recurrence are followed in surgical series describing hernia repair with component separation, restoration of abdominal wall function, patient mobility and activity, and minimization of discomfort are also goals of repair. A retrospective review of traditional OCS repairs and minimally invasive component separation identified higher rates of postoperative pain when the minimally invasive technique was used.¹⁹ In this population, quality of life (QOL) after ventral hernia repair in the setting of component separation has been analyzed prospectively alone²⁹ or compared with patients who underwent open ventral hernia repair with mesh^{12,14} to better characterize differences in QOL after hernia repair with or without component separation.

Varying methods of assessing QOL are employed between the studies. Thomsen issued a questionnaire addressing general health and wellness as well as hernia-specific fields, including hernia-related pain, gravity, and mobility limitation during various movements and body positions. A verbal rating scale was also employed to assess patient-perceived impairment of mental and physical health.²⁹ Pre- versus postoperative analgesic and alcohol consumption were also assessed. In this case series of 19 patients undergoing primarily bilateral (94.7%) endoscopic component separation, 15 patients (78.9%) were available for follow-up at 2 and 6 months after surgery. The authors found a decrease in mean alcohol consumption, while 12 patients (80%) reported stable or decreased analgesic consumption at long-term follow-up. No subgroup analysis was performed to establish the effect of postoperative complications on long-term QOL, and no comparison group of patients whose hernia was repaired via open component separation was available.

Klima et al. assess QOL in patients undergoing OCS compared with that reported by patients undergoing open ventral hernia repair without component separation.¹² In this study, the Carolinas Comfort Score (CCS) is employed to assess QOL, pain, hernia-related movement limitation, and mesh sensation during eight daily activities. This study compared QOL as measured by the CCS at 1 month and up to 12 months after surgery in cohorts of patients

undergoing open ventral hernia repair with ($n = 74$) or without ($n = 154$) component separation. QOL outcomes by aggregate CCS score and by category (pain, movement limitation, and mesh sensation) were equivalent at the measured time points, which suggests that hernia repairs requiring component separation for fascial closure do not adversely affect QOL in short- or long-term follow-up when compared with standard ventral hernia repair procedures. In this series, wound morbidity was higher in the component separation group, including skin dehiscence and seromas that required intervention; however, these patients were not isolated for subgroup QOL analysis.

ROBOTIC POSTERIOR COMPONENT SEPARATION TECHNIQUE: TRANSVERSUS ABDOMINIS RELEASE

Posterior component separation may be utilized when defect size does not require anterior component separation, after previous anterior component separation with recurrent hernia, or in patients at high risk of wound complication following an open anterior component separation.²⁰ Early reports of robot-assisted ventral hernia repair focused on assessment of feasibility and safety. The dexterity of the surgical robot was cited as a potential improvement over traditional laparoscopic ventral hernia repair with mesh, because tackers were replaced by continuous intracorporeal suture fixation of the mesh to the abdominal wall (intraperitoneal onlay) with a resulting potential decrease in the chance of postoperative pain. Robotic primary closure of the defect, also differing from laparoscopic ventral hernia repair, was cited as a potential benefit.^{30,31} Robotic ventral hernia repair with mesh has also modified traditional laparoscopic ventral hernia repair by developing preperitoneal flaps for mesh placement and subsequent running peritoneal closure to avoid intraperitoneal mesh placement; as described by Sugiyama et al., the defect itself is not closed due to size.³²

The robotic platform has now been utilized to perform posterior component separation procedures involving the posterior rectus sheath: the Rives-Stoppa retrorectus hernia repair and the transversus abdominis release (TAR).³³ Robotic Rives-Stoppa repairs with component separation have been described with three ports placed lateral to the linea semilunaris in locations similar to those used for laparoscopic ventral hernia repair.

The camera is placed in the central trocar, and the working arms are placed inferior to the lower costal margin and superior to the ASIS. Care must be taken to provide adequate distance from these bony prominences to prevent robotic arm pressure and risk of patient injury. Ideally, working ports should each be placed 8–10 cm cranial or caudal to the camera port location and slightly anterior to the camera.

After dividing adhesions of bowel or omentum to the posterior surface of the abdominal wall, the posterior rectus sheath is incised 1 cm lateral to the midline, and the rectus

abdominis is reflected anteriorly to develop a retrorectus space while placing downward traction on the posterior rectus sheath fascia. The retrorectus dissection continues laterally until the edge of the rectus muscle at the linea semilunaris is encountered. If Rives-Stoppa-type retrorectus repair is intended, mesh is placed and the posterior rectus sheath is closed in running fashion with absorbable suture.

Transversus abdominis release is begun by dividing the fibers of the transversus abdominis (TA) muscle as they insert onto the lateral extent of the anterior surface of the posterior rectus sheath. The muscle is pushed laterally to expose the complex of transversus abdominis fascia and underlying peritoneum. The lateral-to-medial oriented muscle fibers of the TA muscle are visualized, and an initial incision into this layer will expose the muscles. The TA is then divided approximately 1 cm from its medial insertion using monopolar electrocautery-linked Hot Shears (Intuitive Surgical, Inc., Sunnyvale, California). During this portion of the procedure, close attention must be paid to the bowel deep to the muscular division to ensure no thermal injury to the bowel. If possible, neurovascular bundles passing from the interoblique space into the rectus muscles should be preserved to prevent rectus atrophy. As with open posterior component separation, the robotic arms provide downward tension to the posterior rectus sheath, while dissection is carried out bluntly, primarily pushing the TA muscle laterally to create a pocket for the mesh.

This dissection separates muscle fibers inserting onto the inferior costal margin and the pubic symphysis for full muscular release. A similar dissection is carried out on the contralateral side, which requires placement of mirror-image lateral abdominal or flank incisions on the contralateral side. Depending on which robotic platform is used, this may require robot undocking and relocation to the opposite side or rotating the operating room table 180° (da Vinci Si, Intuitive Surgical, Inc.) or reorienting the robotic arms with less movement of the robotic tower (da Vinci Xi, Intuitive Surgical, Inc.).

After measuring the size of the defect, a piece of mesh allowing adequate defect overlap is introduced into the abdomen and placed in the retromuscular space; this is typically performed through the 12 mm port placed in the contralateral flank that served as the previous camera port. A trans-abdominal suture may be employed to suspend the mesh while it is unfurled and situated in the retrorectus space with the robotic arms. Mesh fixation can be performed robotically with interrupted or running suture; when performing a Rives-Stoppa repair, mesh fixation can also be performed with tacking devices employed by a bedside surgeon. The mobilized posterior rectus sheath is then closed primarily; this is performed in running fashion with V-Loc suture (Medtronic, Minneapolis, Minnesota). A closed suction drain can be placed between the peritoneum and mesh (TAR) or in the retromuscular space (Rives-Stoppa repair) through one of the working port insertion sites, as muscular mobilization for full TAR has been carried lateral to port placement sites.

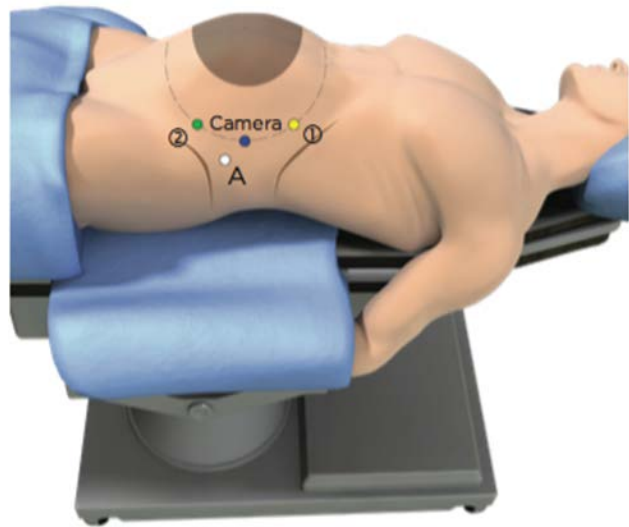


Figure 96.8 Port placement for robotic posterior component separation. The hernia defect is shaded. Eight millimeter robotic arms (1,2) with a central 12 mm camera port are placed in the lateral abdomen. An assistant port (A) can also be used for retraction assistance, initial adhesiolysis, or introduction of the mesh. (Figure reproduced with permission from Intuitive Surgical, Inc., Sunnyvale, California, 2016.)

A 21-patient series reported by Warren et al. found equivalent incidence of surgical site infection with shorter hospital length of stay by comparing patients treated with open versus robotic retrorectus repair with mesh.³³ Fewer wound infections were observed in the robotic group; however, this difference did not reach statistical significance. No difference was found in hospitalization cost between the two groups; this observation may be due to shorter hospital length of stay in the robotic group or decreased cost of robotic surgery over time. Further studies with longer follow-up periods are required to fully describe outcomes following robotic posterior component separation compared with the open and endoscopic component separation techniques (Figure 96.8).

ADJUNCTIVE MEASURES TO ASSIST FASCIAL APPROXIMATION

Primary fascial closure of a prolonged open abdomen or in hernias with extensive loss of abdominal domain may be complicated by lateralization of the abdominal wall musculature and fascia. Though component separation may be required in these patients, even a maximal 20 cm release afforded by bilateral external oblique release may be inadequate to fully approximate the midline fascia. In these select settings, preoperative interventions have been employed to expand the abdominal wall or to allow improved relaxation of lateralized muscle and fascia.

Though McAdory et al. have described administering progressive preoperative pneumoperitoneum with inert medical gas via a laparoscopically placed transabdominal catheter to prepare patients with abdominal loss of domain for the increased intra-abdominal pressure that accompanies reconstitution of the abdominal wall,³⁴ injection of botulinum toxin into the lateralized musculofascial complex has been more extensively described as a preoperative method to facilitate abdominal wall reconstruction. Building on imaging evidence of hernia defect size decrement with onabotulinumtoxinA (Botox, Allergan, Dublin, Ireland) injections into the lateral abdominal musculature,³⁵ Elstner et al. report a case series of ultrasound-guided bilateral transversus abdominis, internal oblique, and external oblique Botox injections prior to laparoscopic ventral hernia repair with mesh for patients with large ventral incisional hernias.³⁶ This study found a significant decrease in hernia defect size resulting from the muscular relaxation, a technique that the authors term a “chemical components relaxation.” Six patients in this series required LCS with partial external oblique release to achieve midline fascial reapproximation without tension. There were no complications relating to Botox injection, and all defects were closed.³⁶

Botulinum toxin injection represents an adjunctive technique that is safe and effective in patients with large defects in whom component separation may not fully cover the defect based on preoperative imaging. When performed, components relaxation of the lateralized musculofascial complex is performed at least 3 weeks prior to planned hernia repair to optimize muscular relaxation. The components relaxation effect typically lasts for up to 3 months. A similar approach has also been incorporated into the management of the open abdomen by Zeilinski et al. who perform ultrasound-guided abdominal wall musculature Botox injections in patients with an open abdomen or patients undergoing repeated procedures.³⁷ The authors advocate the use of this technique to avoid bridging mesh placement and to avoid extensive dissection and traditional components separation in patients recovering from recent critical illness or trauma. Performing traditional component separation in this setting may preclude future options for hernia repair should a hernia develop. Especially in patients with risk factors for wound complications, a combination of Botox injection and LCS may allow for fascial approximation while mitigating the wound morbidity of OCS.

CONCLUSION

Component separation to obtain fascial closure is a useful technique in the setting of large ventral hernias, open abdomen closure following trauma or multiple abdominal procedures, or after excision of infected mesh. To mitigate the substantial wound morbidity associated with classical open component separation by external oblique

release, laparoscopic component separation and posterior component separation techniques are attractive options. Detailed knowledge of the fascial and muscular layers of the abdominal wall is required to perform these procedures. Though wound morbidity is lowered by the use of laparoscopic techniques, hernia recurrence with primary tissue repair remains higher than in series of open ventral hernia repair with preperitoneal or retromuscular mesh reinforcement. To optimize hernia repair and lower recurrence, the use of mesh reinforcement of the midline closure is suggested.

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Biomaterial considerations in laparoscopic hernia repair

BRENT D. MATTHEWS

INTRODUCTION

Since the first publications of laparoscopic repair of inguinal hernias (1992) and ventral hernias (1993) with mesh, these minimally invasive techniques have evolved significantly due to technical advancements in the procedures.^{2,14} Patients may experience a reduced length of stay and lower incidence of wound morbidity after laparoscopic ventral hernia repair and less postoperative pain and an earlier return to work after laparoscopic inguinal hernia repair compared to open techniques.³⁻⁶ Data from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) revealed that utilization rates of laparoscopy for inguinal hernia repair and ventral hernia repair are 27% and 22%, respectively.^{1,23} In recent years, innovative designs in mesh and fixation devices have facilitated the use of laparoscopy for inguinal and ventral herniorrhaphy. More specifically, novel materials altered to manipulate the fiber size and pore size, thus mesh density (g/m^2), or prosthetic material designs having partially absorbable composite materials and absorbable or nonabsorbable barrier layers for intraperitoneal placement are design modifications to provide patient-centered alternatives to mesh selection. A surgeon's understanding of the structural aspects of mesh designs and their potential influence on patient outcomes such as hernia recurrence, functionality, and postoperative pain is critical. This chapter provides an overview of prosthetic material designs for laparoscopic inguinal and ventral hernia repair with an appraisal of implications on clinical outcomes important to hernia patients and the surgeons who provide care for them.

PHYSICOMECHANICAL PROPERTIES OF MESH

Mesh composition

Permanent prosthetic materials are typically utilized for elective laparoscopic inguinal and ventral hernia repair. Completely resorbable or biologic meshes will not be referenced in this chapter. These single-polymer meshes are most commonly composed of polypropylene, polyester, or polytetrafluoroethylene. Examples are PROLENE Mesh, Ethicon Inc., and ProLite Mesh, Atrium Medical Corp., representing polypropylene; Parietex Lightweight Monofilament Polyester Mesh, Covidien, Ltd., representing polyester; and INFINIT Mesh, W.L. Gore & Associates Inc., representing polytetrafluoroethylene. A unique feature for several meshes utilized for laparoscopic inguinal hernia repair is a three-dimensional or anatomically curved mesh to mimic the contour of the inguinal floor. 3DMax, Bard/Davol Inc., and PROLENE 3D Patch, Ethicon Inc., are polypropylene meshes with such designs. Such designs are not available for laparoscopic ventral hernia repair.

The most comprehensive categorization of permanent synthetic mesh for inguinal and ventral hernia repair was recently introduced by Deeken and Lake.⁹ Reinforced meshes are constructed of a permanent and resorbable polymer. Per Deeken and Lake, the function of these resorbable fibers is to provide a gradual transfer of load back to the native tissue (abdominal wall or inguinal floor) as the repair site remodels, regenerates native tissue, and integrates through the interstices/pores of the mesh.⁹ Many of the low-density or "lightweight" meshes have this

feature, such as polypropylene-based meshes ULTRAPRO Mesh, Ethicon Inc., and SERAMESH PA, Serag-Wiessner. Barrier meshes, most appropriate for laparoscopic intraperitoneal onlay ventral hernia repair, are either composite or noncomposite. The barrier function is to minimize adhesions or ingrowth into the mesh, since it is exposed to the viscera (stomach, small intestine, colon, liver, and bladder). Composite meshes are composed of two discrete layers, the structural mesh and the antiadhesion barrier, with the two layers sewn or vacuum-pressed together.⁹ An example of a permanent barrier, composite mesh is Composix, Bard/Davol Inc., and resorbable barrier, composite meshes are C-QUR Mesh, Atrium Medical Corp. (**Figure 97.1a**), Ventralight ST Mesh, Bard/Davol Inc., or Parietex Composite (PCO) Mesh, Covidien, Ltd. Noncomposite, barrier meshes are composed of a single layer of material that exhibits antiadhesion characteristics on one side and tissue ingrowth features on the other side. An example of this type of mesh is DUALMESH Biomaterial, W.L. Gore & Associates Inc. (**Figure 97.1b**).

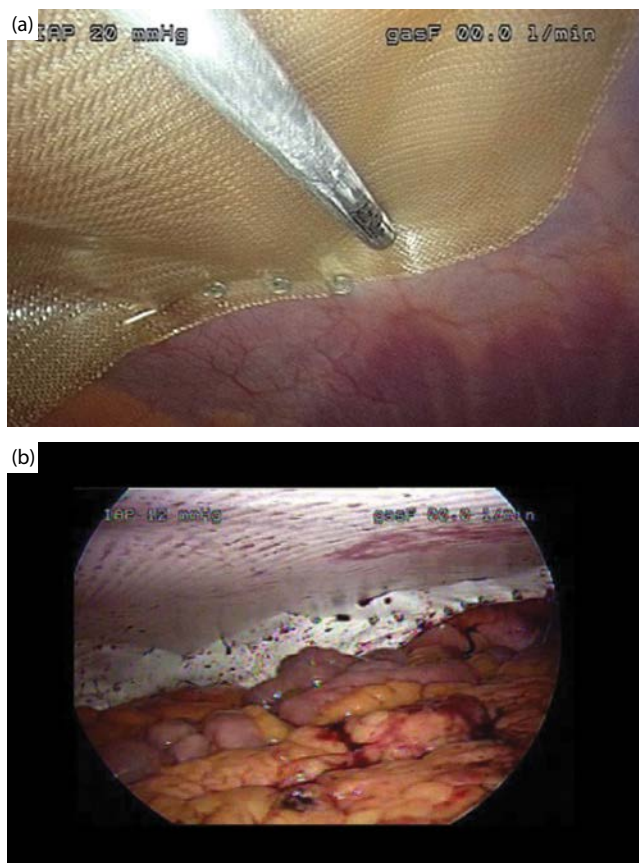


Figure 97.1 Laparoscopic ventral hernia repair: (a) Resorbable barrier, composite mesh (C-QUR Mesh [Atrium Medical Corp.]). (b) Noncomposite, barrier mesh (DUALMESH Biomaterial [W.L. Gore & Associates Inc.]).

Biomechanical characterization

The unique combination of parameters, such as size and shape of the interstices/pores (mm^2) and filament type, diameter (μm), thickness (mm), and density (g/m^2), determine the mechanical properties of prosthetic mesh. The morphometric or mechanical properties can ultimately have consequences on mesh integration or the inflammatory reaction. This could subsequently alter the stability of the mesh-tissue interface, impact hernia recurrence rates, or cause chronic pain. There is still a significant gap in relating mechanical properties of prosthetic materials to clinical outcomes. Nevertheless, a fundamental understanding of mesh properties has been elucidated over the past 5 years through investigative partnerships between surgeons and engineers. Using standard techniques described by ASTM International and the *in vitro* application of relevant physiologic loads to simulate abdominal wall function, the physicomaterial properties of mesh utilized for laparoscopic inguinal and ventral hernia repair have been characterized.^{7,8} Mechanical properties such as suture retention strength (N), tear resistance (N), tensile strength (MPa), burst strength (N/cm), and strain (%) have been calculated to depict differences in the materials based on the combination of parameters previously described. In addition, the effect of repetitive loading on the mechanical properties of these materials has been determined.¹⁰ Any deterioration of the tensile strength of the mesh or an increase in the ability of the mesh material to stretch with repetitive loading could potentially lead to a less desirable functional result or hernia recurrence. Through these studies, important differences were discovered in the physicomaterial properties of polypropylene, polyester, polytetrafluoroethylene, partially absorbable, and barrier-coated meshes frequently used for laparoscopic inguinal and ventral hernia repair. In general, as the density of mesh increases (ultra lightweight to lightweight to medium weight to heavyweight), the mechanical properties of the materials can be described as becoming stronger, stiffer, and less elastic. This does not necessarily equate to a more favorable clinical outcome. Other interesting properties arose, such as anisotropy, the property of being directionally dependent, implying different mechanical properties when oriented in different directions. The clinical relevance of these studies is described later, but the characterization and categorization of these materials have provided a basic understanding of how the structural aspects of each mesh design potentially influence functionality, outcome, and failure. Thus, it will be critical that future clinical trials be performed to assess patient-centered outcomes related to different mesh types based on their unique or differentiable mechanical properties.

Laparoscopic ventral hernia repair and, to a lesser extent, laparoscopic inguinal hernia repair are dependent on fixation to provide acute tensile strength immediately following repair. A combination of suture and mechanical fixation for

laparoscopic ventral hernia repair and mechanical fixation for laparoscopic inguinal hernia repair is typically applied. This ensures mesh stability to prevent migration of the mesh during tissue integration and short-term failure. The consequences of mechanical fixation on the physicomaterial properties of mesh are only now being evaluated.^{15,26} Many of the meshes evaluated exhibited damage in the form of reduced tensile strength and increased extensibility after the application of tacks (mechanical fixation). Higher-density meshes ("heavyweight"), which had smaller pore size and larger filaments, were influenced negatively by the application of a mechanical fixation device (helical titanium tacks) compared to the larger-pore and smaller-filament meshes. In addition, altering the deployment angles of different tackers affected the acute mesh-tissue fixation strength *in vitro*. As the number of mechanical fixation devices available for clinical use has increased over the past 5 years, these studies highlight the need to more fully understand what combination of mechanical fixation and mesh type is optimal to provide the most durable repair. Alternative types of fixation, such as fibrin sealants, have been evaluated. Used most frequently for laparoscopic inguinal hernia repair in the preperitoneal space and rarely for laparoscopic ventral hernia repair against the peritoneum, the effectiveness of fibrin sealant as a fixation device for mesh fixation is likewise altered by the composition and physical structure of the mesh in relationship to the mesh-tissue interface. Although likely effective with certain circumstances, fibrin sealants are currently not U.S. Food and Drug Administration-approved for mesh fixation, considered "off-label" use in the United States, and should be used cautiously with certain materials.

BIOMATERIAL PERFORMANCE IN LAPAROSCOPIC HERNIA REPAIR

There are a considerable number of preclinical studies evaluating the biocompatibility and performance of mesh for laparoscopic hernia repair. Features such as adhesion formation, adhesion tenacity, mesh contracture, tissue integration (mechanical/histologic), and inflammatory response have been characterized to differentiate the materials to support clinical decision-making. Unfortunately, translating this information from experimentation *in vivo* (rodent, rabbit, canine, and porcine) to patients has significant limitations. Although preclinical studies are critical to safeguard safety and efficacy of biomaterials prior to clinical use, differences in anatomy, biomechanics, and physiologic response restrict the translation of results. Additionally, conflicts of interest between industry, who typically support these preclinical studies, and translational researchers potentially limit the reliability of these studies and likely impede the reporting of negative outcomes. Longitudinal, postmarket clinical trials evaluating biomaterials for laparoscopic inguinal and ventral hernia repair without comparative, case-matched cohorts also have similar limitations.

Nevertheless, numerous prospective, randomized trials of laparoscopic inguinal hernia repair evaluating the effect of biomaterials on clinical and quality of life outcomes have been completed. Unfortunately, there is a major gap in comparative clinical outcomes research evaluating biomaterials for laparoscopic ventral hernia repair. A summary of clinical trials evaluating biomaterials for laparoscopic inguinal and ventral hernia repair follows.

Laparoscopic inguinal hernia repair

Sajid et al. completed a systematic review and meta-analysis evaluating the effectiveness of lightweight mesh against heavyweight mesh following laparoscopic inguinal hernia repair.²¹ Primary outcomes from the 11 prospective, randomized clinical trials were recurrence, physical function, and quality of life. Hernia recurrence rates were similar for lightweight and heavyweight meshes. However, lightweight mesh reduced the incidence of chronic groin pain, groin stiffness, and foreign body sensations. In a prospective, randomized clinical trial with 3 years follow-up, Peeters et al. analyzed the effects of lightweight and heavyweight meshes on male fertility, chronic pain, and recurrence after laparoscopic inguinal hernia repair.¹⁹ Recurrence rates were comparable between lightweight and heavyweight mesh. In addition, quality of life (SF-36) and chronic pain (McGill Pain Questionnaire) were similar. There was a decrease in sperm motility in patients after laparoscopic inguinal hernia repair with a lightweight mesh compared to patients operated on with a heavyweight mesh at 1 year postoperative follow-up. This particular outcome was not present at 3 years follow-up. In a prospective, randomized clinical trial comparing lightweight polypropylene to heavyweight polyester mesh for laparoscopic inguinal hernia repair, Wong et al. reported similar clinical outcomes for discomfort, foreign body sensation, and recurrence during long-term follow-up.²⁵ This was an unusual comparison, as virtually all trials have evaluated the same polymer. There was a significantly higher incidence of seromas in the heavyweight polyester group. The TULP trial, a prospective, double-blind, randomized control trial was completed to assess chronic postoperative pain, quality of life, and recurrence following implantation of a lightweight and heavyweight polypropylene mesh in laparoscopic total extraperitoneal inguinal hernia repair.¹² In this cohort of 950 patients, the incidence of pain was defined according to the International Association for the Study of Pain. The presence of relevant pain (greater than 4 on a numeric rating score of 0–10) was significantly higher in the lightweight mesh group after 1 and 2 years' follow-up. In addition, the recurrence rate was significantly higher in the lightweight group (2.7%) compared to the heavyweight group (0.8%). No differences in foreign body sensation or quality of life scores were detected between the lightweight and heavyweight groups.

Although lightweight mesh was developed to decrease the foreign body response (inflammation and contracture) and improved mesh-tissue compliance to optimize patient-centered outcomes, most level 1 clinical studies have not revealed a clinical advantage over heavyweight mesh for laparoscopic inguinal hernia repair. In fact, in some instances, lightweight mesh has an unfavorable outcome. Clinical trials evaluating lightweight and heavyweight mesh for open inguinal hernia repair differ in clinical and quality of life outcomes. Therefore, it is imperative for surgeons to have a clear understanding of the clinically relevant and meaningful outcomes for patients so that benefits from advances in biomaterial technology can be applied when performing a minimally invasive or open approach.

Laparoscopic ventral hernia repair

Prospective, randomized, or case-matched clinical trials comparing meshes utilized for laparoscopic ventral hernia repair have not been completed. This will likely require registries such as the Americas Hernia Society Quality Collaborative (AHSQC), Herniated German Registry, Danish Hernia Database, or others to report clinically pertinent outcomes. In fact, the latter two postmarket surveillance registries noted a similar finding to an interim safety analysis of a randomized controlled trial that closed after the enrollment of 25 patients due to a 20% recurrence rate after 6 months in one cohort (lightweight mesh/absorbable tacker—strap design) compared to 0 recurrences in the other group (lightweight mesh/absorbable tacker—screw design).¹⁸ Subsequently, the mesh with a 20% recurrence rate was voluntarily recalled by the manufacturer.

An additional consideration when assessing mesh utilized for laparoscopic ventral hernia repair is the effectiveness of the barrier. In a clinical trial, this can only be evaluated accurately through reoperation (**Figure 97.2**).

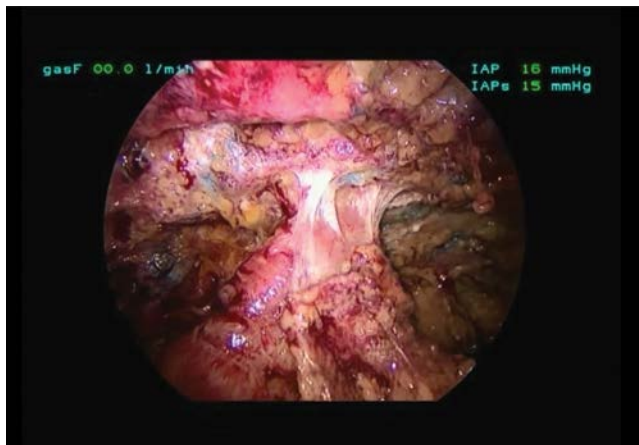


Figure 97.2 Adhesions of small intestine to a resorbable barrier, composite mesh (PROCEED Surgical Mesh [Ethicon Inc.]) 23 months after laparoscopic ventral hernia.

Effectiveness can be determined by complication avoidance (enterotomy) and operative efficiency (operative time, conversion rates from laparoscopic to open). Jenkins et al. and Patel et al. have reported findings on laparoscopic re-exploration after intraperitoneal placement of mesh. In both studies, the most common reason for laparoscopic re-exploration was a recurrent ventral hernia.^{11,17} Jenkins et al. reported an enterotomy and cystotomy rate of 1.4% and 1.4%, respectively. Only 2.8% of cases were converted to an open procedure. A metric of operative efficiency, adhesiolysis time/mesh surface area (min/cm²), favored the noncomposite, barrier mesh over the permanent barrier, composite mesh and resorbable barrier, composite meshes in this pilot study. The rate of enterotomy/small bowel resection was 4% in the Patel et al. study. This was primarily due to small intestine-mesh adhesions in patients who presented with a small bowel obstruction. The rate of bowel obstruction and small bowel resection was lowest in the noncomposite, barrier mesh cohort. Sharma et al. reported a 5% access injury rate and 6.3% conversion rate from laparoscopic to open in 76 patients who had intraperitoneal mesh.²² Although the types of mesh encountered at re-exploration were identified, metrics to differentiate effectiveness of the barriers were not provided.

Anecdotally, central mesh failure after a bridged laparoscopic ventral hernia has been described²⁴ (**Figure 97.3**). It has been reported after mesh reinforcement with lightweight polyester mesh during open ventral hernia repair.²⁰ Postoperative abdominal wall bulging seems to be more pronounced after bridged laparoscopic ventral hernia with lightweight versus heavyweight mesh, but once again this has not been substantiated by outcomes studies. Clinical trials evaluating primary fascial closure versus nonclosure of hernia defect during laparoscopic ventral hernia repair with mesh have not demonstrated a decrease in hernia recurrence.¹⁶ The long-term effectiveness of lightweight mesh for laparoscopic ventral hernia repair remains unknown.

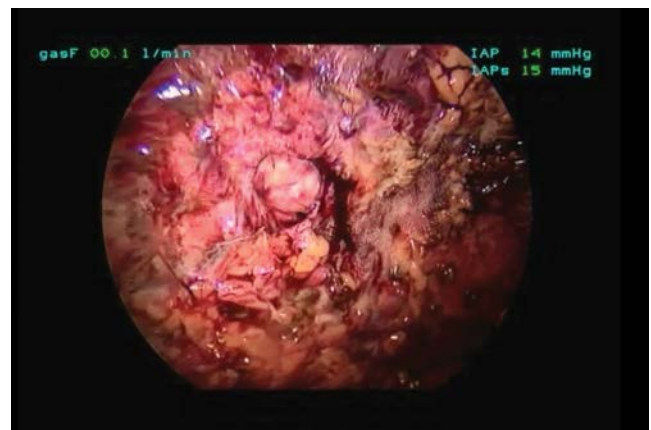


Figure 97.3 Central mesh failure 14 months after laparoscopic ventral hernia repair with a lightweight, resorbable barrier, composite mesh.

CONCLUSION

It is essential that surgeons appreciate aspects of mesh design and its impact on patient outcomes. A novel mesh package label to include physical properties (base material, barrier, pore size, and weight) and biomechanical properties (stiffness, tear strength, and ball burst strength) has been proposed by Kahan and Blatnik to improve surgeon recognition and differentiation of the numerous materials available.¹³ Knowledge of biomaterials' effect on outcomes is more applicable to laparoscopic inguinal hernia repair, as hernia recurrence and quality of life outcomes (functionality, postoperative pain, etc.) have been demonstrated in clinical trials to be impacted by mesh selection. There is a significant gap in clinically relevant, patient-centered outcomes evaluating biomaterials utilized for laparoscopic ventral hernia repair. Postmarket surveillance will be the responsibility of registries such as the AHSQC that collect patient-centered data and provide ongoing performance feedback to clinicians with improvement based on analysis of collected data and collaborative learning. The recently launched AHSQC ORACLE (Outcomes Reporting App for CLinician and Patient Engagement) will also guide surgeons on mesh selection for laparoscopic ventral hernia repair.

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Laparoscopic incisional and ventral hernia repair

BRUCE J. RAMSHAW, LISA A. CUNNINGHAM, AND H. CHARLES PETERS

INTRODUCTION

Abdominal wall hernias are a common, yet complex, problem encountered by general surgeons. Despite the large volume of hernia repairs performed, there remains no clear consensus on any single best technique. Issues that contribute to this lack of agreement include advancements in laparoscopic technology, the influx of new mesh materials onto the market, and an increasingly complex patient population. Over the last two decades (1995–2015), the laparoscopic repair of ventral and incisional hernias has been validated by several published clinical studies and is one of the more common laparoscopic procedures performed.^{1–6} It is based on the principles of the Rives-Stoppa repair, in which mesh is placed deep to the hernia defect and fixed with wide mesh coverage to healthy abdominal wall fascia using full-thickness permanent sutures. In contrast to open repair, the laparoscopic approach places mesh inside the peritoneal cavity, rather than in the retrorectus position, a technique made potentially safer by the advent of new bilayered biosynthetic materials that promote tissue ingrowth on one side and minimize the potential for ingrowth on the other. This positioning of mesh against the posterior aspect of the abdominal wall with wide overlap of the hernia defect has a potential mechanical advantage over previously described inlay and onlay techniques. Intra-abdominal pressures disperse forces over the entire abdominal wall, potentially holding the mesh in place if there is adequate overlap. Laparoscopic ventral hernia repair allows for clear visualization of the entire anterior abdominal wall, wide mesh coverage beyond the defect, and secure fixation to abdominal wall fascia.

INDICATIONS

Standard indications for operative hernia repair include symptomatic hernia, a bulge or deformity causing a poor

cosmetic appearance, risk of incarceration and/or strangulation, and abdominal wall dysfunction. First, if the hernia causes pain and discomfort such that it limits a patient's ability to perform activities of daily life or significantly decreases quality of life, repair should be considered. Second, hernias can create a bulge in the abdominal wall that negatively affects appearance, and these can be repaired for cosmetic reasons, if the risks of surgery are not prohibitive. Third, abdominal wall hernias carry a risk for incarceration and strangulation of visceral organs. Risk of incarceration or strangulation likely varies based on several factors, including defect size, location, hernia characteristics, and history of previous incarceration. The fourth indication usually occurs in combination with one of the others, and that is abdominal wall dysfunction. The abdominal wall plays an important role in balance, ambulation, lifting, and many other activities of daily life. A ventral hernia can displace the abdominal wall musculature from its typical anatomical location, creating an uncoordinated abdominal wall with the potential for loss of form and function. The presence of abdominal wall dysfunction that inhibits the performance of activities of daily life and decreases quality of life should prompt consideration for operative repair.

PREOPERATIVE PLANNING

Patient selection and timing of surgery are factors that can contribute to successful outcomes and attempt to avoid complications. A laparoscopic approach may be a choice in nearly all patients with a ventral hernia; however, surgeon experience and patient selection should be considered, as many hernia repairs require advanced laparoscopic skills, and an open approach may be a better choice in some circumstances. More challenging situations should be avoided early in a surgeon's learning curve, including patients with multiple comorbidities; multiple previous attempts at hernia

repair; previous intra-abdominal placement of mesh; the presence of enterocutaneous fistulas; chronic hernias with loss of abdominal domain; and hernias in atypical locations such as suprapubic, flank, and parastomal hernias. Regardless of surgeon experience, conversion to an open repair is not a failure or complication if performed using good surgical judgment for the benefit of the patient.

As with any surgical procedure, patients should be counseled regarding the potential risks and benefits of surgery and should have appropriate expectations about the postoperative course, recovery, and potential complications. It is normal to have pain at incision sites and at suture and tack fixation sites after surgery. In most cases, this will necessitate hospital admission for adequate control of pain. In some patients, particularly those at high risk for conversion to open surgery and for large defects, a transversus abdominis plane (TAP) block or placement of an epidural catheter for pain can be helpful. For larger hernia repairs, repair of incarcerated hernias, or repairs that require extensive intra-abdominal adhesiolysis and bowel manipulation, hospital admission should be anticipated for adequate pain control and while awaiting return of bowel function.

One important risk to discuss with patients is the potential for bowel injury and the subsequent changes in management should it occur. This is particularly important for patients with large hernia defects, multiple comorbidities, multiple previous abdominal surgeries, multiple previous abdominal wall hernia repairs, and previous placement of mesh. Such patients need to be prepared for the possibility of conversion to an open operation, delayed mesh placement, and prolonged inpatient hospitalization. All patients with morbid obesity are counseled regarding the increased risk of complications, including an increased risk for hernia recurrence. Obese patients are encouraged to lose weight prior to hernia repair and are often sent for bariatric consultation. Those actively using tobacco are referred for cessation therapy, and hernia repair is typically delayed until smoking cessation has been achieved.

EQUIPMENT AND MATERIALS

One important consideration in performing a laparoscopic ventral hernia repair is the choice of prosthetic material to be used in the repair. Although there is no ideal mesh, a mesh designed for laparoscopic intra-abdominal placement would be strong and durable, resist infection, be immunologically inert, and have dual-surface properties such that the abdominal wall side will facilitate tissue ingrowth and incorporation into the fascia and muscle, and the peritoneal side will minimize adherence to the visceral organs and prevent ingrowth of tissue. Any macroporous mesh placed in an intraperitoneal position should be avoided because of the potential long-term risk of bowel erosion, fistula formation, and small bowel obstruction. There are several mesh products available that are appropriate for intra-abdominal

placement. Most mesh selection is based on personal experience and anecdotal evidence, as a paucity of human data are available comparing the long-term outcomes of different mesh products. Collection of real-world outcomes with various mesh products will allow for the potential to match types of mesh and techniques with patient subpopulations using complex systems science tools such as predictive, dynamic algorithms. Although this type of use of data is common in other industries, it has not yet been utilized in health care.

OPERATIVE TECHNIQUE

After induction of general anesthesia, the patient is positioned supine on the operating room table with arms tucked at the sides. Prophylactic antibiotics against skin flora are routinely given, and an orogastric tube is placed for gastric decompression, as well as a Foley catheter for decompression of the bladder. Sequential compression devices and subcutaneous heparin are utilized for deep venous thrombosis prophylaxis based on individual patient risk factors. Monitors are placed based on the location of the hernia defect(s). The patient is shaved, prepped, and draped widely to allow for the lateral placement of ports, usually beyond the anterior axillary line. A plastic protective drape is often used to help avoid mesh-to-skin contact. Several methods may be used to gain safe entrance into the peritoneal cavity, including the open Hasson technique, a Veress needle technique, and direct laparoscopic guidance using a dilating optical port. We routinely use blunt digital dissection through a 12 mm skin incision at either the left or right costal margin at the tip of the 11th rib, which usually corresponds to the anterior axillary line. A 10 mm balloon-tip port is then used for secure port placement. Insufflation with CO₂ is begun at this point. We have recently begun using a low-pressure insufflation system, typically with a maximum pressure setting of 8 mmHg (although for obese patients the setting may need to be higher). This may help reduce postoperative gas-related symptoms such as shoulder pain. We routinely place two or three additional 5-mm ports, depending on the size and location of the hernia defect(s). For midline hernias, ports are placed in the lateral abdominal wall, which allows for broad coverage of the hernia defect with mesh. All adhesions to the abdominal wall are typically lysed using blunt and sharp dissection, although some surgeons do use energy sources for lysis of adhesions. Electrocautery or other energy sources should be used sparingly to avoid inadvertent thermal injury to visceral organs. Bleeding may be controlled with pressure, hemoclips, or electrocautery after all nearby visceral organs have been safely identified and cleared away. Usually, a plane can be developed between the abdominal wall and the adherent abdominal contents, which allows for safe and gentle dissection. When no discernable plane is apparent, the abdominal wall is sacrificed in order to protect the bowel. This dissection is performed cautiously to minimize the risk of an identified bowel injury,

or more importantly, an inadvertent unidentified injury to the bowel. If an enterotomy occurs, the injury should be repaired either laparoscopically or through an open incision, and then the adhesiolysis may be completed. The surgeon must use his or her best judgment to determine the need for converting to an open operation and for the appropriate timing of mesh placement. Although there are reports of placing mesh after bowel injury, our preferred practice is to delay mesh placement. We have, based on various factors, proceeded with mesh placement after laparoscopic repair of the enterotomy, admitted these patients, placed them on intravenous antibiotics for several days, and then returned to the operating room on day 3, 4, or 5 for delayed mesh placement if no signs of sepsis were apparent; we have also converted to an open operation in some cases. If a strategy to delay mesh placement is chosen and a reoperation is performed within 3–5 days, there are generally minimal to no adhesions, and repeat adhesiolysis adds little time or morbidity to the operation.

After adhesiolysis, the boundaries of the fascial defect are identified, and the hernia contents are reduced. This can be done with gentle traction using atraumatic laparoscopic graspers and external manual compression on the hernia. If omentum is incarcerated within the hernia, the major risk associated with reduction is bleeding. This can be managed with pressure, hemoclips, ENDOLOOPS, or electrocautery. If bowel is incarcerated in the hernia or densely adherent to the hernia sac, excess tension should be avoided, as this could cause a traction injury to the bowel. Sharp dissection may be necessary to dissect the bowel free from the hernia sac. In some cases, it may be necessary to open the fascial defect with sharp dissection to adequately and safely reduce the hernia contents. The viability of incarcerated bowel is then assessed, and necrotic or nonviable bowel is resected. For most hernias, further dissection and exposure of the posterior abdominal wall surrounding the fascial defect are necessary prior to the placement of mesh. This may involve division of the falciform ligament and median umbilical ligament and/or mobilization of the bladder and exposure of the pubic symphysis and the Cooper's ligaments. This is performed with electrocautery or ultrasonic dissection because of the vasculature present within these structures. Ultimately, this creates a musculofascial surface against which the prosthetic mesh is placed. At this point, the fascial edges of the hernia defect should be identifiable circumferentially, which allows for accurate measurement of the hernia defect. A spinal needle placed perpendicularly through the abdominal wall is used to mark the fascial edges. The pneumoperitoneum is decreased, and the defect is measured. The hernia can also be measured intracorporally using a sterile plastic ruler, instrument, or suture. If multiple hernias are present, the maximal distance between all defects is measured as long as they are close together. Alternately, separate meshes may be used for defects that are far apart from each other. A mesh designed for intra-abdominal placement is then selected to overlap all fascial

defect margins by at least 5 cm. It is trimmed, as necessary, and then marked for orientation and placement of sutures. The four cardinal permanent sutures are placed equidistant around the mesh, usually at the superior, inferior, and bilateral positions. Markings on the plastic drape or skin help to plan the site of externalization of the cardinal stay sutures. The mesh is then rolled like a scroll along its horizontal axis with the sutures tucked in the middle. Next, a 5 mm grasper is inserted through a port opposite the 10 mm balloon port and is brought through the abdominal wall at the balloon port site. The 10 mm port is removed, the mesh is placed in the grasper, and the grasper is brought into the abdomen with the mesh. An external clamp can help push the mesh through the 10 mm incision site, and a 5 mm laparoscope may also be used to visualize mesh insertion. The balloon-tip port is then reinserted, and the mesh is unfurled and oriented inside the abdomen using the markings on the plastic drape or skin as a guide. The cardinal sutures are then brought through the abdominal wall at predetermined positions using a transfascial suture passer. There are several mesh deployment devices on the market. These devices may help make mesh placement and positioning more efficient and more accurate.

The individual sutures at the cardinal sites are brought through the fascia approximately 1 cm apart, which allows for that portion of the abdominal wall to be incorporated into that suture. After each pair of sutures is brought through the abdominal wall, they are clamped with a hemostat. The next suture site is identified by grasping the mesh and bringing it up to the abdominal wall while applying tension to the sutures clamped in the hemostat. In this manner, adjustments are made for a more accurate, tension-free placement of the mesh. After all four cardinal sutures are brought through the abdominal wall, tension is applied, and the mesh is evaluated for position. When the mesh is appropriately placed, the tension on the sutures should create a diamond shape on the undersurface of the mesh. If this does not occur, one or more sutures should be adjusted. This is performed by releasing the suture from the hemostat, pulling the sutures back into an intra-abdominal position, and then repositioning them using the suture passer. With the cardinal sutures tied holding the mesh in place, the border of the mesh is then tacked to the abdominal wall at 1 cm intervals. This precludes bowel or other abdominal contents from slipping over the edge and herniating above the mesh, before the process of mesh incorporation and neoperitonealization occurs. Although a variety of absorbable fixation devices are now available, patients with thick scar tissue, dense abdominal walls, and the use of expanded polytetrafluoroethylene mesh may require a permanent tacker for adequate fixation. Additional permanent transfascial sutures are then placed at 3–5 cm intervals around the outside of the mesh for further fixation. For large single defects, sutures may be spaced more closely together compared with defects that are small or multiple small "Swiss cheese"-type defects. These are placed using a transfascial suture passer in

a fashion similar to that previously described for the initial sutures. At the conclusion of the procedure, the mesh should tautly approximate and follow the curve of the abdominal wall without wrinkles.

A final survey is performed to ensure that hemostasis is achieved and to assure that no other injuries have occurred. If bowel viability was in question before, it is reevaluated. If nothing further needs to be performed and no injuries are identified, then the 10 mm balloon-tip port is removed, and the fascial defect at that site is closed laparoscopically using a 0 Vicryl suture. Alternatively, a port closure device may be used. The remaining ports are removed under visualization, and pneumoperitoneum is evacuated. Skin incisions are closed with absorbable sutures, and the skin at the transfascial suture sites is inspected and released from the deep tissues with a hemostat to eliminate any permanent skin puckering. The Foley catheter and orogastric tubes are removed in the operating room for small defects. For larger defects, the Foley catheter may be maintained for an additional 24–48 hours if indicated, and the patient is not discharged.

POSTOPERATIVE CARE

Postoperative care is supportive while awaiting return of bowel function. Patients with small hernias requiring minimal manipulation of bowel during surgery can be started on a clear liquid diet immediately, given oral pain medications, and potentially discharged on the day of surgery or the day after once adequate pain control is achieved. Those patients with large, chronic hernias, or those with incarcerated bowel, and those who require long and arduous adhesiolysis generally take liquids and/or ice chips initially in small amounts and are supported with intravenous fluids and intravenous or epidural pain control. Early ambulation and appropriate prophylaxis against deep venous thrombosis are recommended based on the risk profile for each patient, and all patients are offered an abdominal binder when ambulating for the first several weeks as well as ice and/or heat for their comfort. Follow-up in the clinic is scheduled for 2–4 weeks after discharge from the hospital.

VARIATIONS OF STANDARD TECHNIQUE: DEFECT CLOSURE

One criticism of the laparoscopic technique for ventral hernia repair is that the hernia defect is not closed, and the hernia sac is left in place, essentially guaranteeing the formation of a postoperative seroma. However, these are often asymptomatic and are of no clinical concern. The published data show a postoperative seroma rate as high as 56% based on clinical examination and 100% when evaluated radiographically by ultrasound.^{7,8}

The laparoscopic ventral hernia repair also leaves some patients with an abdominal wall bulge and persistent abdominal wall dysfunction. This is not a complication of

the operation, because the hernia defect is appropriately covered, and the risk for incarceration and strangulation is eliminated. However, this is a limitation of the operation if the patient has a negative opinion of how he or she looks. In at least one study, there was evidence of dissatisfaction due to these issues.⁹ The lack of medialization of the rectus muscles may also have a negative impact on abdominal wall function. In an attempt to improve cosmetic and functional outcomes and ultimately improve patient satisfaction, we have started performing a primary closure of the fascial defect using absorbable sutures prior to mesh placement in select patients. After complete adhesiolysis, reduction of hernia contents, and exposure of the entire fascial defect, absorbable sutures are placed in a figure-eight fashion through the abdominal wall to close the hernia defect. A 2 mm skin incision is made over the hernia, a 0 polydioxanone suture is brought through the abdominal wall and healthy fascia 1 cm from the edge of the hernia and is then brought back through the other side of the hernia at a similar position using a transfascial suture passer. This is then repeated once with the same suture such that a figure-eight configuration is performed. This is repeated at 1 cm intervals until the entire defect is closed. After all sutures have been placed, the pneumoperitoneum is evacuated, and the sutures are tied down. Pneumoperitoneum is then reestablished, and the suture line is inspected for integrity. In addition to performing primary fascial closure, we still place a mesh with dimensions similar to what would be placed in the absence of fascial closure for broad coverage.

LAPAROSCOPIC MYOFASCIAL SEPARATION OF COMPONENTS AND ADVANCEMENT FLAPS

In a smaller group of select patients, a bilateral laparoscopic myofascial separation of components and advancement is performed prior to repair of the hernia. The initial port placement is performed two fingerbreadths below the costal margin at the anterior axillary line. A transverse incision is made through the skin followed by subcutaneous dissection until the external abdominal oblique musculofascial layer is exposed. This layer is incised with electrocautery, and digital dissection is performed to establish a space between the two muscle layers. A 10 mm dilating balloon is inflated under visualization with a 10 mm, 0° laparoscope. Appropriate position is verified by visualization of external and internal oblique muscle layers coming together medially at the edge of the rectus sheath.

Next, the balloon is deflated, a 10 mm balloon-tip trocar is placed, and pneumatic insufflation is started with carbon dioxide set at a pressure of 10 mmHg. A 5 mm port is then inserted inferiorly at the lateral aspect of the intramuscular space created. Either a hook or scissors connected to electrocautery can be used to completely incise the external oblique musculofascial layer 1–2 cm lateral to the rectus sheath. This is performed superiorly to several centimeters above the costal margin and inferiorly toward the pubis. In some

cases, this may require placement of an additional 5 mm medial port. To ensure maximal release and advancement, the incision is carried anteriorly through the Scarpa layer of the subcutaneous tissue. During dissection, extra care must be taken superiorly to maintain hemostasis, as this area above the costal margin is muscular and well vascularized. Ultrasonic dissection may be more hemostatic than electrocautery in this area.

ROBOTIC VENTRAL/INCISIONAL HERNIA REPAIR

Recently (2010–present), the laparoscopic robotic system has been used to perform minimally invasive ventral/incisional hernia repair using a traditional laparoscopic approach (with robotic internal suturing of the mesh to the abdominal wall instead of using tacks) and a robotic transversus abdominis release (TAR) type of abdominal wall reconstruction. Advantages of the robot for traditional lap ventral hernia repair include ease of defect closure with robotic suturing techniques and the potential to replace traditional methods of fixation with a running robotic suture between the edge of mesh and abdominal wall, potentially resulting in less pain. Concerns about this technique include costs and the ability to consistently get sutures into the musculofascia with a laparoscopic approach. A robotic TAR has the potential advantage to avoid wound and mesh complications. Concerns are cost and the mounding of skin and soft tissue for wide defects.

ANATOMIC VARIANTS: EPIGASTRIC, SUPRAPUBIC, AND FLANK HERNIAS

Ventral hernias extending superiorly to the xiphoid process or inferiorly to the pubic tubercle pose an additional challenge for the laparoscopic surgeon. Epigastric hernias usually require high division of the falciform ligament for adequate exposure of the entire fascial defect. Anchoring transfascial sutures are not usually placed above the costal margin because of the risk for bleeding and chronic pain. In this situation, the sutures are placed lower on the mesh in position with the costal margin, and the superior aspect of the mesh is tacked near the diaphragm. It is critical that the mesh has adequate overlap of the fascial defect; however, care should be taken to avoid injury to the pericardium. The initial superior suture is usually placed several centimeters below the top edge of the mesh and fixed at the xiphoid process. This allows the top portion of the mesh to provide overlap to the diaphragm.

Complete visualization of suprapubic hernias may require mobilization of the bladder and exposure of the pubic tubercle and bilateral Cooper's ligaments. Similar to transabdominal preperitoneal inguinal hernia repair, care must be taken not to place sutures and tacks in positions

that cause bleeding or chronic pain. Anchoring transfascial sutures are placed above the pubic tubercle and superior to the iliopubic tract. The remaining overlap of mesh can then be secured to the Cooper's ligaments bilaterally with tacks. Lateral fixation with sutures and tacks should be placed superior to the iliopubic tract bilaterally.

Flank hernias are defined as abdominal wall defects that occur between the costal margin and the iliac crest lateral to the anterior axillary line and medial to the spine. These may be challenging to diagnose by physical examination alone, since some of these patients will have a persistent flank bulge after a flank incision due to muscle atrophy in the absence of a hernia. A computed tomography (CT) scan may be helpful for diagnosis and preoperative planning. Adequate paraspinous musculature needs to be present to allow for posterior mesh fixation. To repair a flank hernia, the patient is positioned in the lateral decubitus position with the hernia side up. Initial access and ports are placed in the midline with additional ports placed as needed. The lateral posterior peritoneum is dissected to allow access to the retroperitoneum and to expose the psoas and paraspinous muscles. This may require medial mobilization of the colon, kidney, and ureter. For larger hernia defects, inferior dissection to expose the Cooper's ligament and iliopubic tract and superior dissection to the diaphragm may be necessary. Once the entire hernia defect is exposed and measured, mesh appropriate for intraperitoneal placement is selected and trimmed to allow for at least 5 cm of hernia overlap. The mesh is secured with transfascial sutures and tacks in a fashion similar to ventral hernia repair. The posterior suture closest to the spine is the first suture placed, as this is the most critical suture due to spatial limitations.

RESULTS OF TREATMENT

Laparoscopic repair of ventral and incisional hernias is a well-established procedure that has been validated by several large retrospective case series and smaller prospective randomized trials. The majority of these studies favor the laparoscopic technique over conventional open repair with mesh because of a reduction in wound complications, mesh infections, and lower rates of hernia recurrence. One of the earliest large studies to evaluate laparoscopic repair of ventral/incisional hernias included a retrospective review of 850 consecutive patients from four surgeons.¹⁰ This series represented a cross-section of patients with ventral hernias, including the extremes of age, morbid obesity, various comorbidities, and previous attempts at hernia repair. The average operative time was 120 minutes, and 3.6% of patients required conversion to an open operation. Intraoperative complications included intestinal or bladder injury in 1.7% and 1 perioperative mortality due to a myocardial infarction on postoperative day 1. The most common postoperative complications included prolonged ileus in 3%, prolonged seroma in 2.6%, and prolonged pain in 1.6%. Over an average follow-up of 20 months, the recurrence rate was 4.7%,

which compared favorably to the wide-ranging 12%–52% recurrence rate seen with open ventral hernia repair. There have now been many prospective, randomized trials comparing laparoscopic and open ventral/incisional hernia repairs. Overall, these studies conclude that the laparoscopic repair of ventral hernias is a safe, feasible, and effective alternative to open ventral hernia repair. A major advantage of the laparoscopic approach is the decreased wound and mesh complication rate. Some studies also suggest a lower length of stay and recurrence rate for the laparoscopic approach.

The most common complications after laparoscopic ventral hernia repair are prolonged ileus, prolonged seroma, and prolonged pain. However, the most feared complication is enterotomy, particularly a missed enterotomy, which can be a deadly event. A literature review of 3,925 patients after laparoscopic ventral hernia repair showed an overall enterotomy rate of 1.78%, the majority of which were identified at the time of surgery.¹¹ The mortality rate for all laparoscopic ventral hernia repairs was 0.05%. If an enterotomy occurred and was identified, the rate was 1.7%, and for a missed or delayed enterotomy, the mortality rate was 7.7%. Prompt recognition of enterotomy intraoperatively, as well as early suspicion for missed or delayed enterotomy postoperatively based on patient presentation, is essential to limiting this complication and minimizing mortality.

APPLYING PRINCIPLES OF CLINICAL QUALITY IMPROVEMENT

In the past 4 years, we have applied the principles of clinical quality improvement to the group of patients with ventral/incisional hernia who undergo laparoscopic ventral hernia repair. Some of the process improvement attempts we have implemented include a multimodal perioperative pain and enhanced recovery program, including the use of long-acting local anesthetic nerve blocks; low-pressure pneumoperitoneum; and preoperative optimization of the patient's medical, nutritional, and emotional states. We

also applied the principles of predictive analytics to identify patient groups at high risk of recurrence (prior recurrence, high body mass index, etc.) and use a more durable mesh with permanent fixation in these patients. We also employ a patient-centered team approach for care, with a patient care manager who engages the patient and family in a shared decision process in an attempt to determine the optimal treatment decision for each patient. As part of the decision process, patients are offered watchful waiting with strategies to manage their hernia nonoperatively, and open operations, including abdominoplasty with abdominal wall reconstruction, in addition to a laparoscopic approach.

SUMMARY

The laparoscopic technique for ventral and incisional hernia repair is safe and effective and can be appropriately applied to most patients. It can have the benefits of shorter operative times, decreased complications, shorter hospital stays, and lower recurrence rates. New techniques are evolving that may further decrease complications, improve abdominal wall function and cosmetic result, and ultimately increase patient satisfaction.

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Robotic transabdominal preperitoneal inguinal hernia repair

FAHRI GOKCAL AND OMAR YUSEF KUDSI

INTRODUCTION

Inguinal hernia repair is one of the most common surgeries in the United States, with between 700,000 and 800,000 performed in 2003.¹ There has been a progressive evolution of inguinal hernia repair since the description of laparoscopic repair by Ger, who reported a laparoscopic closure technique of the internal ring.² During the early days of the laparoscopic era, there had been negative outcomes, such as high recurrence rates and postoperative pain; however, minimally invasive inguinal hernia repair gained better outcomes with increasing experience of surgeons. It is believed that some of the primary reasons for those poor results in laparoscopic repair were due to the fact that mesh reinforcement was not routine, as well as postoperative pain resulting from tack placement in the laparoscopic technique.³

The two laparoscopic herniorrhaphy techniques are currently being performed for inguinal hernia repair, whether by the transabdominal preperitoneal (TAPP) or totally extraperitoneal (TEP) approach. Both techniques are acceptable treatment options for inguinal hernia repair, although there is insufficient data showing the superiority of one technique over the other.^{4,5}

Several studies have shown that laparoscopic repair has been associated with decreased postoperative pain, earlier return to work, and improved cosmetic outcomes when compared with an open approach.^{3,6,7} Despite these documented advantages of the laparoscopic approach, the open approach has been favored among surgeons in North America,⁸ even for situations where published guidelines recommend a laparoscopic approach, such as bilateral hernia and recurrent hernia.^{5,9} The laparoscopic technique requires intracorporeal suturing skills and a long learning curve, which might contribute to surgeons' preference for an open approach.

The robotic platform with the da Vinci (Intuitive Surgical, Inc., Sunnyvale, California) system has offered three-dimensional vision through a computer interface, a stable platform, and increased dexterity with 7° of freedom at the articulating wrist to facilitate minimally invasive surgery. In the matter of robotic suturing and knot tying, a study showed that surgeons were significantly faster than they were at standard laparoscopy.¹⁰ Moreover, the robotic platform, with advanced ergonomics for the surgeon, permits difficult cases to be performed. For these reasons, the robotic transabdominal preperitoneal (rTAPP) approach may have a role in complex inguinal hernia repair, such as recurrent cases after prior posterior repair (TEP or TAPP), cases with previous prostatectomy, cases that involved an incarcerated nonreducible inguinal hernia even after induction of anesthesia, and cases of scrotal inguinal hernia.⁹ The safety, feasibility, and reproducibility of the application of the robotic system in performing this procedure have been described in the literature.^{9,11-14}

In this chapter, we discuss the technical aspects of robotic transabdominal preperitoneal repair for inguinal hernias.

PATIENT SELECTION

The indications for rTAPP inguinal hernia repair are the same for open inguinal hernia repair. Robotic repair may be appropriate in cases of bilateral inguinal hernias and recurrences. Patients who have unilateral primary hernias are appropriate candidates for this approach when the surgeon is comfortable with the technique. Also, superiority of robot use over open technique has been shown in obese patients.¹⁵ The contraindications of this procedure are analogous to the laparoscopy contraindications in addition to the situations that can preclude the use of a mesh, such as grossly contaminated abdominal cavity.

SURGICAL TECHNIQUE

Preoperative preparation

Preoperative preparation includes thromboprophylaxis, body hair clipping, and prophylactic antibiotics. Foley catheterization is not generally required. We ask all patients to empty their bladders immediately before operation and encourage the anesthesiologist to restrict perioperative fluid to minimize postoperative urinary retention. In cases of a potentially difficult procedure, the bladder may be emptied to minimize the risk of bladder injury as well as to obtain adequate space. The instrument table is set up in the same fashion for every case to provide workflow efficiency.

Patient positioning, access, trocar placement, docking

The patient is positioned supine with both arms on the operating table. The patient should be fully secured to the surgical table to prevent slipping off and should be properly padded to obstruct robotic arm collision during operation. After general anesthesia induction, asepsis is achieved via chlorhexidine and the surgical drapes are placed over the patient, providing the entire abdominal area including inguinal region cover.

There are a number of techniques to achieve a pneumoperitoneum. Using an open technique (Hasson) at the position of planned first trocar is a valid entry option into the abdominal cavity. However, our preference is that a Veress needle is inserted at Palmer's point, 1–2 cm below the left costal margin at the left midclavicular line, to obtain pneumoperitoneum. Then the initial port is inserted in the abdominal cavity. Access may also be obtained by optical trocar by using 0° camera.

Particular attention must be paid to achieve adequate distance between each trocar and surgical target to prevent robotic arms collision and extensive troubles. For this purpose, the commonly applied rule is that a minimum of 8 cm of distance be maintained between each trocar and an ideal distance of 10–20 cm is suggested between the trocars and the surgical target. Three trocars, two of which are for instruments (we generally utilize bipolar Maryland forceps, monopolar scissors, and needle driver) and one of which is for a camera, are usually used. Apart from conventional laparoscopy, trocars are placed in a horizontal line at 4 cm above the umbilical level, each lateral trocar is positioned in the midclavicular line, and the center trocar is positioned just off the midline (**Figure 99.1**). It should be emphasized that trocars should not be placed too lateral in patients with a smaller body habitus, as this would cause difficulty when it comes to suturing laterally. At this time, some surgeons prefer introducing the required materials, such as mesh and selected sutures, into the abdominal cavity through one of the trocars in order to minimize robotic arms undocking.

After ensuring trocar placement safely and properly, the patient is shifted for final position in 15°–20° of

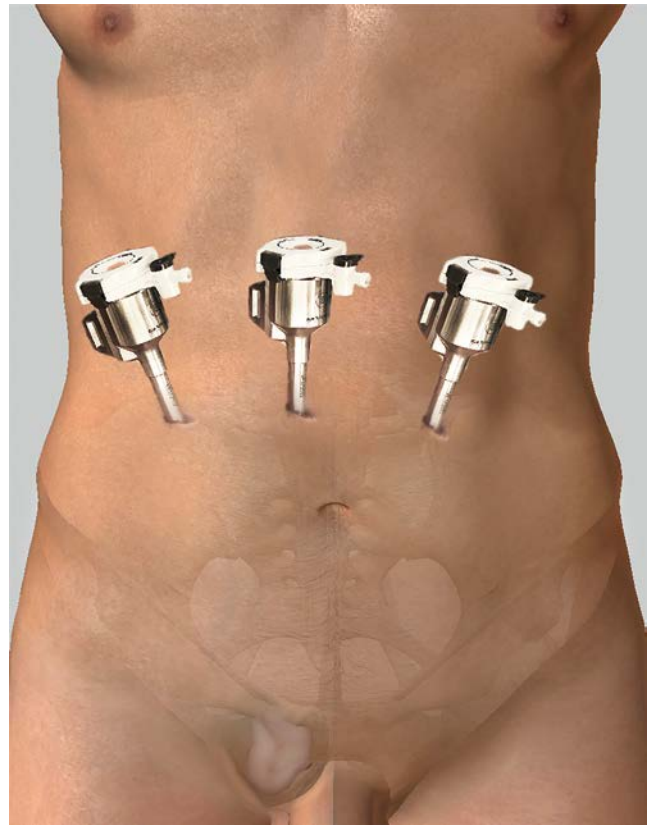


Figure 99.1 Trocar positioning.

Trendelenburg to improve exposure of the working area and to move the abdominal structures from the area of dissection. Slightly flexing the operating table may be beneficial to obtain free movement of the robotic arm in a patient who has a short torso. Patient position should be finalized prior to docking the patient-side cart and must remain constant during operation. The patient-side cart is advanced by an assistant (closely guided by the surgeon) into the correct position, and the docking process is completed after connecting trocars and robotic arms. Of note, with the Si system, the patient-side cart must be positioned at the foot-side of the operating table to achieve “in line” rule, whereas the patient-side cart can be positioned at the patient’s side with the Xi system, as this platform includes an overhead boom allowing the arms to rotate as a group into any orientation.

Initial exposure, preperitoneal dissection, and anatomical landmarks

In cases involving intestinal adhesions, we avoid extensive adhesiolysis unless the adhesions obstruct the view. To avoid visceral injury in cases of sliding or irreducible hernias, neither adhesiolysis nor reduction is performed at the beginning of the case; rather, these procedural steps are performed during preperitoneal dissection and mobilization of the hernia content.

Medial umbilical ligament, lateral umbilical ligament, internal inguinal ring, external iliac vessels, inferior epigastric vessels, gonadal vessels, and arcuate line are the initial landmarks in the peritoneal cavity. The inferior epigastric vessels, the internal inguinal ring with the spermatic vessels, and the vas deferens should be identified. These three structures have been named the “Mercedes-Benz star.”¹⁶

A curvilinear peritoneal incision is performed by monopolar scissors and a bipolar Maryland to enter preperitoneal space 6 cm above the hernia defect, from the median umbilical ligament to the anterior superior iliac spine (**Figure 99.2a**). To be able to visualize the Fruchaud myopectineal orifice, dissection is performed in the preperitoneal avascular plane between the peritoneum and the transversalis fascia. The medial extent of dissection is carried out roughly 3 cm beyond the symphysis pubis to the contralateral side to provide sufficient mesh overlap (**Figure 99.2b**). The lateral extent is the anterior superior iliac spine (**Figure 99.2c**). The caudal extent is 4 cm below the iliopubic tract at the level of the psoas muscle and 2 cm below Cooper’s ligament (**Figure 99.2d**).

Throughout the preparation of the peritoneal flap, the peritoneum should be tracked gently to avoid tearing due to the fact that there is no haptic feedback in robotic platform. Pressing on the peritoneal flap with the sponge, which is prepositioned in the working area, helps minimize the peritoneal tearing risk as well as control minor bleeding.

If there is a disruption in peritoneal integrity, it should be repaired later by absorbable sutures.

The authors’ preference is to first dissect and identify Cooper’s ligament before addressing the rest of the dissection. Cooper’s ligament is a useful landmark, particularly if there is a large hernia sac obscuring the field of dissection. Once this ligament is identified, a lateral dissection of the preperitoneal space is required, leaving the hernia sac dissection until the end. This facilitates identification of the spermatic cord, vas deferens, and the Triangle of Doom. The cord structures are isolated and dissected to identify the indirect hernia sac. This sac is usually found on the anterolateral side of the cord and is adherent to it. The vas deferens and the spermatic vessels should be taken maximum care of when the sac is being separated from the cord.

The peritoneal hernia sac and associated adipose tissue from the hernia (pre-, extra-, and retroperitoneal fat) is reduced toward the middle of the psoas muscle (parietalization). It should also be emphasized to take into consideration the importance of preserving the spermatic fascia and lumbar fascia to protect the vas deferens, nerves, and vessels. Careful sharp dissection with sparing use of monopolar energy is essential to avoid inadvertent injuries. The authors prefer to detach the hernia sac completely from the spermatic cord to avoid seroma formation or hernia recurrence (**Figure 99.3a**). Dissection may be challenging if there

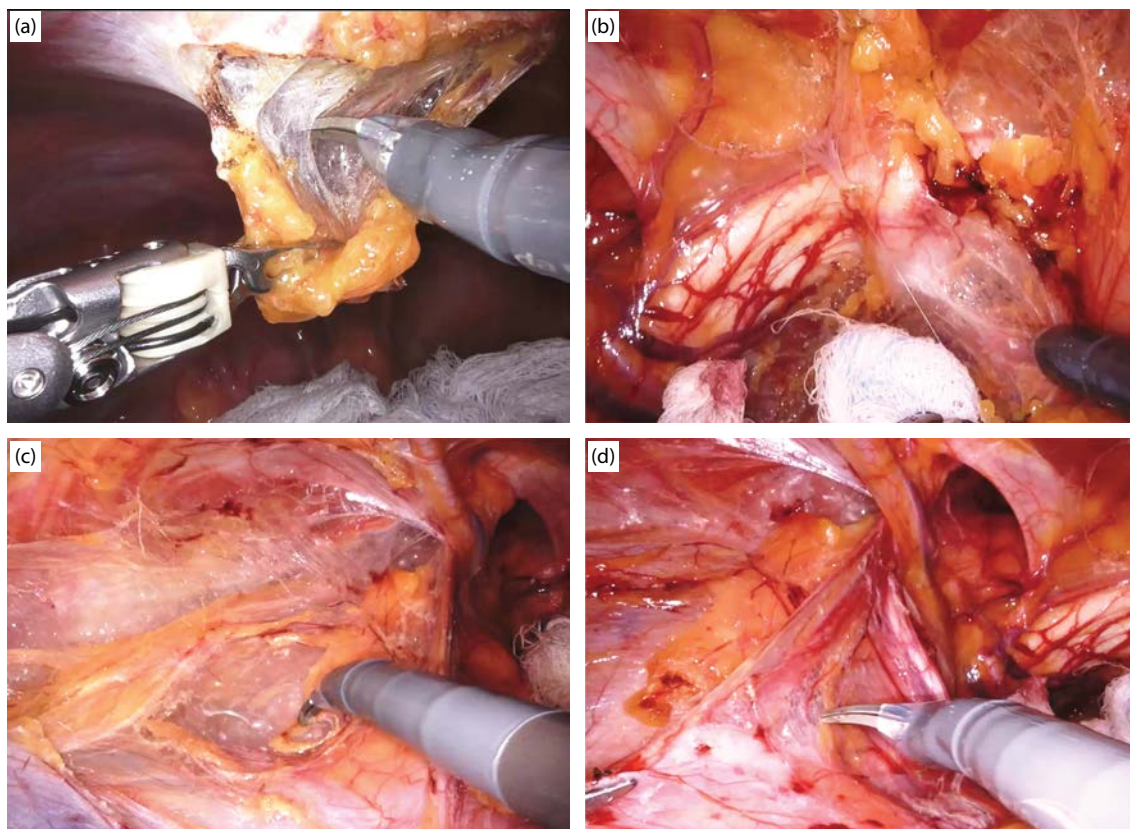


Figure 99.2 (a) Beginning the preperitoneal dissection. (b) The medial extent of dissection. (c) The lateral extent of dissection. (d) The caudal extent of dissection.

are very large hernia sacs like inguinoscrotal hernias. In this situation, the sac may be transected and left in place, being cautious to close the peritoneal defect once the inguinal repair is done. Formation of a hydrocele should be prevented by leaving the distal end of the transected sac open. If the sac is ligated, it should be done at the narrowest point possible to reduce the size of the defect in the peritoneal flap. This allows for an easier closure without deficit. A large indirect sac may be ligated proximally and divided distally, with lower postoperative pain and recurrence rate, but with higher postoperative seroma rate.¹⁷

Direct hernia sacs are easier to reduce than indirect sacs (**Figure 99.3b**). Transversalis fascia, which is a form of pseudosac, may be present after reducing the direct hernia sac. Once the pseudosac is freed, it will typically retract anteriorly into the direct hernia defect. Before placing the mesh, the transversalis fascia is fixated to Cooper's ligament in order to prevent postoperative seroma formation due to dead space. Suturing in small stitch fashion, passing through the pseudosac, increases the effectiveness of the reduction (**Figure 99.3c and d**). Alternatively, the primary closure of direct inguinal hernia defects with a pre-tied suture loop can be used.¹⁷ More effort should be undertaken to reveal and treat occult synchronous femoral hernia, especially in females undergoing inguinal hernia repair.¹⁷

The main anatomical landmarks are shown in **Figure 99.4**.

Mesh placement, fixation, and peritoneal closure

Complete dissection of the retroinguinal space (Bogros' space) ensures flat placement of the mesh, which covers the entire myopectineal orifice without folding. As recommended by the International Endohernia Society (IEHS) guidelines, mesh size of at least 10×15 cm is used. If the patient is big or has a large hernia defect (direct >3 – 4 cm, indirect >4 – 5 cm), bigger mesh (i.e., 12×17 cm or greater) is used.⁵ The mesh should cover without wrinkles all potential hernia fascial defects in the groin, including Hesselbach's triangle, the indirect ring, the femoral ring, and the obturator ring (**Figure 99.5a**). The authors prefer to use the ProGrip Laparoscopic Self-Fixating Mesh, Anatomical Design (Covidien, New Haven, Connecticut). It is a common practice to use at least three fixating sutures (Cooper's ligament, medial to the inferior epigastric vessels, superiolateral of the internal inguinal ring) when using non-self-fixating mesh. For large direct hernias, if the hernia defect is not closed, besides using larger mesh, additional fixation is required around Hesselbach's triangle to prevent mesh migration to the hernia defect.

These fixations can be performed with intracorporeal sutures, as tacks are generally not required. It should be kept in mind that the mesh should not be fully stretched, since it can shrink in certain degrees (10%–30%). The recurrence

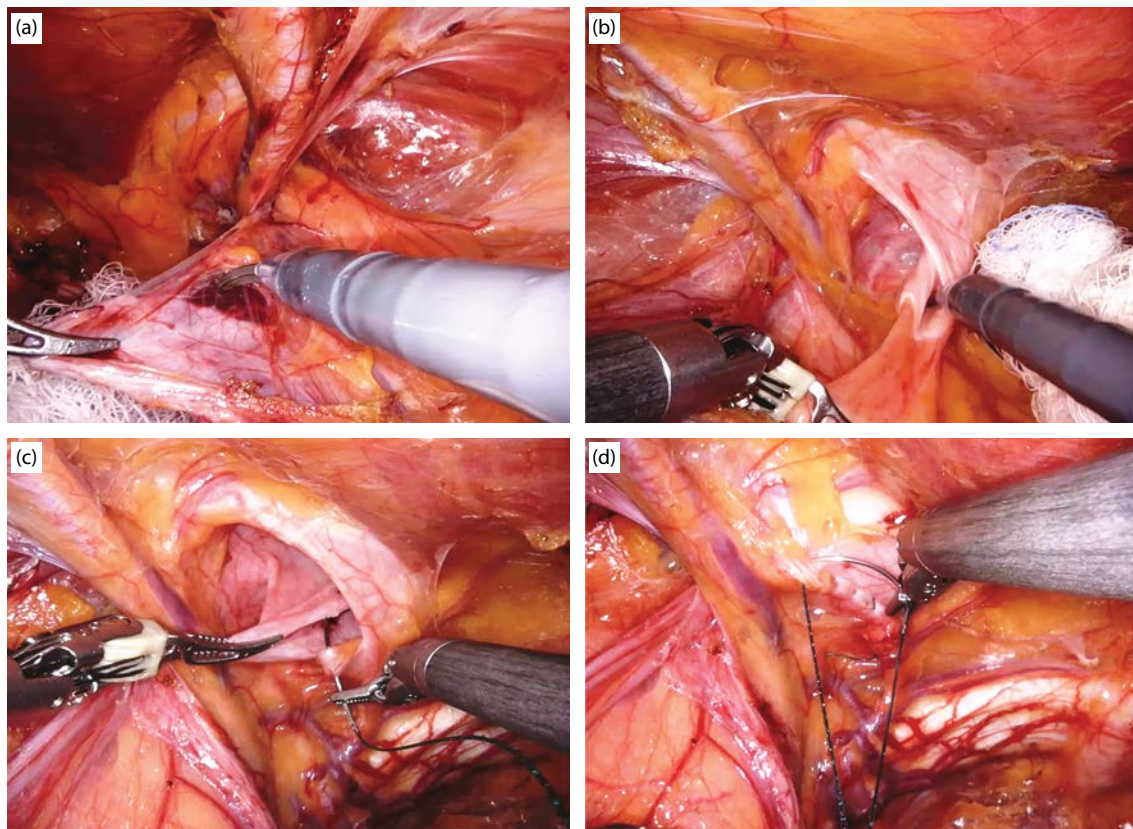


Figure 99.3 (a) Dissection of indirect hernia sac from cord structures. (b) Dissection of direct hernia sac from pseudosac. (c and d) Suturing the direct hernia defect in small stitch fashion, passing through the pseudosac.

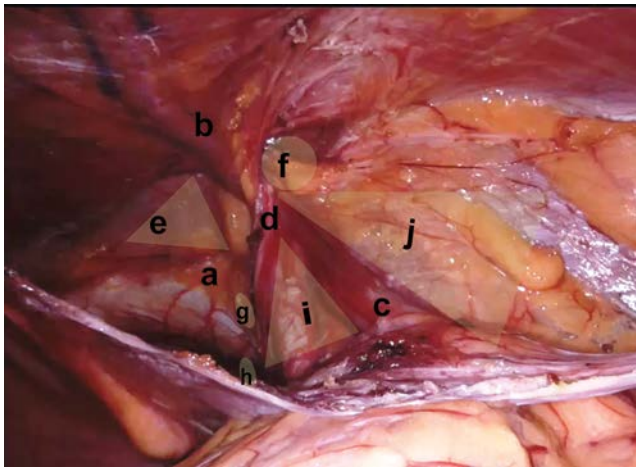


Figure 99.4 Main anatomical landmarks: (a) Cooper's ligament; (b) inferior epigastric vessels; (c) psoas muscle; (d) cord elements; (e) Hesselbach's triangle (direct hernia site); (f) internal ring (indirect hernia site); (g) femoral canal; (h) obturator canal; (i) Triangle of Doom; and (j) Triangle of Pain.

after TAPP is generally inferiorly, resulting from insufficient coverage of the inferior edge of the myopectineal orifice or from migration of the mesh. Therefore, it is very important to confirm mesh positioning during closure and desufflation. It should be kept in mind that the mesh can fold in on itself by the inferior peritoneal flap during suturing.

After adequate mesh fixation and bleeding control are achieved, the next step is to close the peritoneal flap. Rapidly absorbable barbed suture (2-0 V-Loc; Medtronic, New Haven, Connecticut) may be used for this purpose. A running short stitch fashion reduces the risk of small bowel herniation and obstruction in the peritoneal fenestrations. Another benefit of a short-stitch technique for peritoneal closure is that less barbed suture is exposed to the viscera (**Figure 99.5b**). A down-to-up suturing direction may facilitate this step (**Figure 99.5c**). During closure, care is taken to suture peritoneum to peritoneum, since suturing peritoneum to fascia of the posterior rectus sheath may cause postoperative protracted pain. For bilateral inguinal hernias, dissection of the preperitoneal space with two separate peritoneal incisions on each side of the median umbilical ligament instead of one long peritoneal incision may facilitate closure of the peritoneal flap; this not only adjusts the anatomical position of the median umbilical fold, it also minimizes the possibility

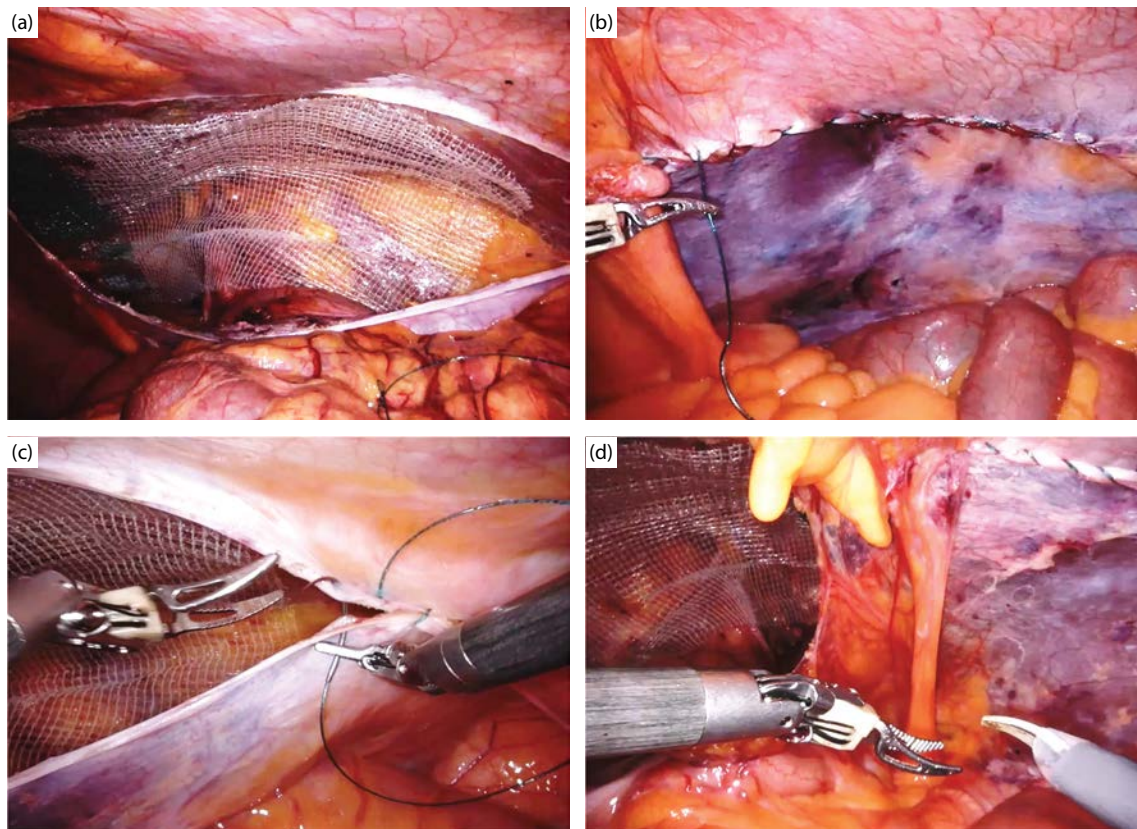


Figure 99.5 (a) Mesh placement to all potential hernia sites. (b) Closure of the peritoneal flap with rapidly absorbable barbed suture in a running short stitch fashion. (c) Suturing peritoneum to peritoneum from down-to-up direction. (d) Keeping intact the medial umbilical fold in order to prevent inadvertent peritoneal tears during peritoneal closure in bilateral hernia repair.

of peritoneal tearing as it reduces weight while suturing the edges of the sagged peritoneal flaps (Figure 99.5d).

At the end of the procedure, it should be checked that the entire mesh is covered with the peritoneal flap to protect the intra-abdominal structures from exposed mesh. The abdominal cavity is evaluated for signs of bleeding or other complications. The trocars are removed, and the pneumoperitoneum is released. If any, the fascia at the 10 mm or larger trocar insertion site should be sutured to decrease the risk of future incisional hernia. A long-acting local anesthetic agent is injected to trocar sites for management of postoperative pain.

Author's experience (O.Y.K.)

There were 118 patients, with a mean age of 58.8 ± 15.4 , who underwent rTAPP inguinal hernia repair from March 2013 to October 2015 in our center. Most of these (83, 70.3%) had unilateral hernia. The remaining 35 patients (29.7%) had bilateral hernia, 11 (9.3%) complex hernia, 8 (6.8%) recurrent hernia, and 3 (2.5%) emergent hernia. The mean surgical time (skin-to-skin: first incision to last closure) was 64.46 ± 35.63 min in unilateral and 80.20 ± 31.72 min in bilateral hernia repair. None of the patients needed a conversion to laparoscopic or open surgery. A total of 113 patients were discharged the same day of the surgeries. The cause of staying at the hospital overnight was urinary retention in two patients and social reasons in the remaining three patients. There was no readmission caused by a surgical reason within 30 days. At the 3-month follow-up, four patients had complications. They were symptomatic seroma requiring drainage at the office in two patients and urinary retention requiring catheterization in two patients. At 1-year follow-up, there were no episodes of recurrence, surgical site infection, testicular atrophy, hydrocele, or orchitis.⁹

POSTOPERATIVE CARE AND FOLLOW-UP

Generally, patients are discharged home on the same day after routine early postoperative care. Patients who require hospital stay usually have preexisting comorbidities that require monitoring after general anesthesia.

The authors prescribe oral nonsteroidal anti-inflammatory agents (NSAIDs) for postoperative pain in the majority of patients. There is no need to prescribe narcotics. Patients are encouraged to resume normal activity after operation. It is advised to avoid lifting heavy objects and doing exhausting activities for 4–6 weeks.

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Robotic ventral hernia repair

FAHRI GOKCAL AND OMAR YUSEF KUDSI

INTRODUCTION

Ventral hernias are one of the major conditions that require abdominal wall reconstruction, which is a rapidly evolving area of surgical interest. The number of abdominal wall reconstructions performed for ventral and incisional hernias in Europe is estimated to be about 300,000/year and 400,000/year in the United States.¹ Abdominal wall reconstruction is performed for the purpose of reestablishing the entirety of the myofascial layer and providing durable coverage while minimizing the risk of hernia recurrence. Several techniques have been practiced for these purposes. The classic open suture techniques are considered only in the presence of very small hernia defects because of high recurrence rates of up to 54% in incisional hernia repair.² Mesh prostheses help to reinforce or bridge the hernia defect, and they can be placed between all layers of the abdominal wall. Recurrence rates of open mesh techniques are lower (15%–30%)²; however, there are specific potential drawbacks, such as seroma, hematoma, and mesh infection.³ Mesh replacement with minimally invasive techniques has gained popularity due to the advantages of reducing complication rates related to wide dissection in open surgery.

Robotic ventral hernia repair is considered a new approach that unites the principles of both laparoscopic and open ventral hernia repair in the minimally invasive arena. One of the important advantages of the robotic platform is to facilitate exploitation of the individual layers of the abdominal wall.

In this chapter, we introduce the execution of abdominal wall reconstruction by robot-assisted surgery.

SURGICAL ANATOMY AND MESH POSITIONING

Simple suture closure of the defect in the abdominal wall is not enough for providing good outcomes in hernia surgery.

Therefore, current hernia repair techniques focus on restoring abdominal wall anatomy and function. The abdominal wall comprises several different layers, including skin, subcutaneous tissue, fascia, muscle, and peritoneum. After emerging from their insertions, three flat muscles of abdominal wall (external oblique, internal oblique, and transversus abdominis) lie on each side of the rectus muscles. Linea semilunaris is formed by the first complex decussation of their aponeuroses, and they split and pass anteriorly and posteriorly around the rectus muscle to form a stout sheath enclosing it. In the middle, linea alba is formed by the second complex decussation of all aponeuroses. As an important anatomical landmark, the arcuate line is located midway between the umbilicus and symphysis pubis. The anterior rectus sheath above the arcuate line is composed of the external oblique aponeuroses and part of the internal oblique aponeuroses. The posterior rectus sheath includes the internal oblique aponeuroses and the transversus abdominis aponeuroses. Below the arcuate line, the external and internal oblique aponeuroses fuse to form the anterior rectus sheath with the posterior rectus sheath being made up of only fascia transversalis. The peritoneum is the innermost layer of the abdominal wall.⁴

Innervation of the anterior abdominal wall is via the anterior and lateral cutaneous branches of the ventral rami of the 7th–12th thoracic nerves, which run in a plane between the internal oblique and transversus abdominis muscles. They perforate the posterior lamina of the internal oblique aponeurosis to innervate the rectus.

The intraperitoneal onlay mesh (IPOM) placement is described as mesh laid on an anterior abdominal wall deep to the peritoneum after inserting into the abdominal cavity. Since the mesh will directly contact intra-abdominal structures in this position, this side of the mesh should be antiadhesive. In the preperitoneal mesh position, as the name implies, mesh is placed anterior to the peritoneum and posterior to the rectus sheath. When the mesh is placed posterior to the rectus muscles, this position is named as

retrorectus. In the transversus abdominis release (TAR) technique, which is described later, the retrorectus layer extends laterally between the transversus abdominis muscle (anteriorly) and the transversalis fascia (posteriorly) when the lateral border of the rectus sheath is dissected.⁵ **Figure 100.1** shows each position of the mesh on abdominal wall layers.

Preoperative evaluation

A thorough history and physical examination are required before robotic abdominal wall reconstruction, as is usual in all surgical approaches. Modifiable risk factors that can affect the wound healing process (diabetes mellitus, obesity, malnutrition, and smoking) should be investigated and corrected before the elective operation, if possible.⁶ In general, preoperative routine imaging is not required in the normal workup of a hernia. However, cross-sectional abdominal imaging with computed tomography (CT) may be performed to understand anatomical detail in patients with small-to-moderate incisional hernia and atypical hernia.

ROBOTIC INTRAPERITONEAL ONLAY MESH REPAIR

The laparoscopic form of the IPOM repair technique was introduced in 1993.⁷ The technique of robotic intraperitoneal onlay mesh (rIPOM) repair is based on this conventional laparoscopic method. It has the advantages of lower rates of surgical site infections and decreased hospital stay as compared to the open technique. However, the laparoscopic method might predispose to acute and extended pain because of circumferential tacks and multiple full-thickness transfascial sutures to secure the mesh adequately.⁸ These kinds of sutures are generally not needed in rIPOM.

The mesh should be compatible with intra-abdominal placement; therefore, the use of coated mesh is mandatory to minimize the risk of adhesive complications. In fact, this bridging-type repair does not truly reconstruct the abdominal wall, even if the hernia is repaired. However, performing defect closure might help restore abdominal wall construction and function. Nevertheless, a classical IPOM remains an ideal alternative in patients who have had previous abdominal surgery, and consequently, whose abdominal wall planes are not suitable for reconstruction.

Surgical technique

The steps of rIPOM repair are similar to those of conventional laparoscopic repair.

PATIENT PREPARATION, POSITIONING, AND INITIAL ACCESS

The patient is positioned supine on the operating table under general anesthesia. Depending on patient- and

hernia-related factors, as well as the preferences of the surgeon and the anesthesiologist, a patient's arms are placed on the board set at 90° from the trunk. Slight flexing of the bed may be beneficial for patients who have a short torso or where there is limited space to adequately insert the trocars. This maneuver increases the distance between the anterior superior iliac spine and the costal margin. Slightly tilting the operating table toward the cart of the robot may contribute to better visualization of the abdominal wall by the camera and to an increase in the range of the robotic arms' motion without obstacle. Access to the abdomen and initiating the pneumoperitoneum may be obtained by either closed (a Veress needle and/or an optical view trocar) or open (Hasson) techniques. The authors prefer direct trocar insertion into appropriate localization after establishment of pneumoperitoneum through a Veress needle inserted at Palmer's point.

TROCAR PLACEMENT, ADHESIOLYSIS, DEFECT CLOSURE

The position of the trocars should allow for a full range of motion and anterior abdominal wall suturing. Generally, three trocars, two of which are for instruments and one of which is for a camera, are used. The extent of the hernia defect, anticipation of the edge of mesh, and maintenance of free movement of the robotic arms should be considered when determining the position of the trocars. The trocars should be positioned on either side of the camera trocar; thus, the "double triangle" rule can be ensured, and they should be placed at a distance of at least 8 cm from one another in order to minimize the mechanical interference of the robotic arms with each other. The camera trocar is also recommended to be placed away from the surgical target to achieve the maximal surgical view, ideally 8–10 cm away from the edge of the mesh that will be used. The first trocar is placed in the left upper quadrant along the anterior axillary line, and the remaining two other trocars are placed roughly 6–8 cm away, preferably taking the C-shape, knowing the limitation of the most inferior trocar (**Figure 100.2**).

Any port placed below the level of the umbilicus near the anterior superior iliac spine (ASIS) while working to repair a centrally located hernia often results in arms collision and extensive troubleshooting; thus, the authors prefer to avoid that location for trocar placement. If present, adhesiolysis of the abdominal wall may be necessary to expose the planned hernia defect (**Figure 100.3a**). Due to the fact that one of the disadvantages of robotic surgery is the loss of haptic feedback, special attention is required to prevent inadvertent bowel injury by way of atraumatic handling.

Closing the hernia defect allows more fascial contact area for the mesh and leads to equalization of the pressure and tension along the mesh and the abdominal wall (**Figure 100.3b and c**). A recent study comparing robotic-assisted laparoscopic ventral hernia repair with closure of fascial defect to laparoscopic ventral hernia repair without fascial defect closure showed decreased recurrence rates and complications in the robotic-assisted patient group.^{8,9}

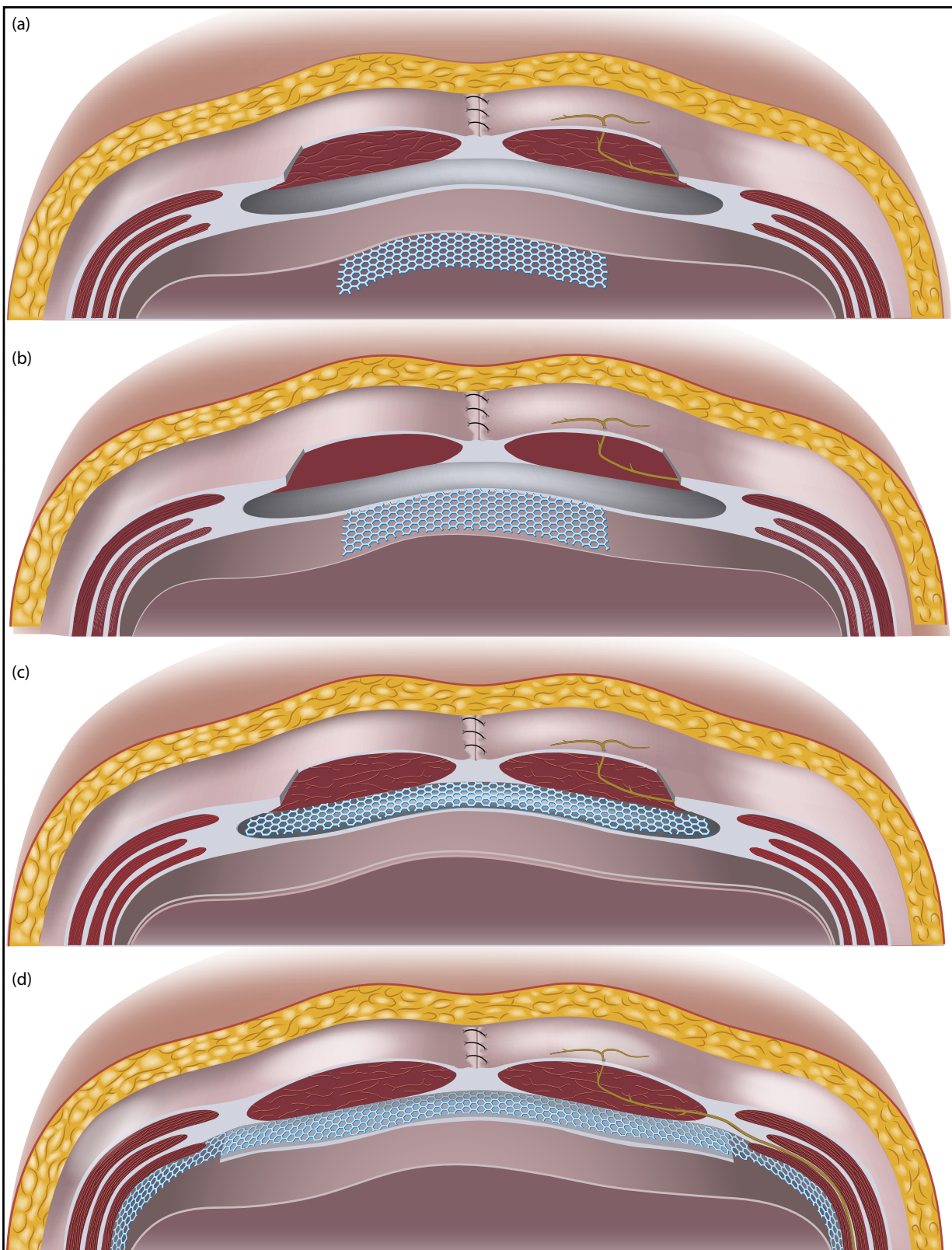


Figure 100.1 Mesh positioning for ventral hernia: (a) intraperitoneal onlay mesh (IPOM); (b) transabdominal preperitoneal mesh (TAPP); (c) retrorectus mesh; and (d) retromuscular mesh with transversus abdominis release (TAR). (Reprinted with permission, *Atlas of Robotic Surgery*, Cine-Med, Inc., copyright 2018.)

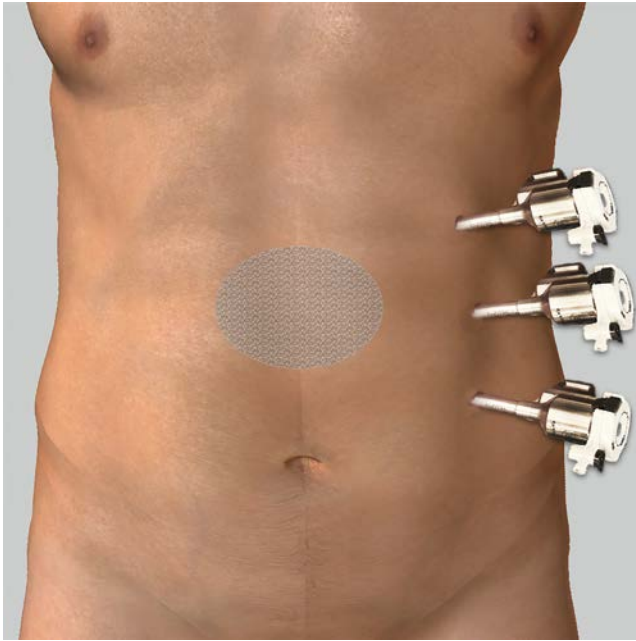


Figure 100.2 Trocar positioning for IPOM and TAPP.

Closing the defect by a robotic platform provides a strong technical ability. It has been reported that the closure of the fascial defect was performed in 69.3% of cases by robotic surgeons at their initial experience.¹⁰

Technically, defects with a diameter less than 10 cm are convenient for primary closure. Reducing pneumoperitoneum pressure to 6–8 mmHg is often necessary. The choice of suture material may vary; in our practice, a long-lasting absorbable barbed suture (STRATAFIX 0 on CT-1 needle, Ethicon, Somerville, New Jersey) is used for primary closure of the hernia defect. The same guideline used for laparotomy closure, which is a small bite technique with taking bites of fascia of 5–8 mm and placing stitches every 5 mm in a shoelace fashion, is preferred.¹¹

MESH PLACEMENT AND FIXATION

A tissue-separating mesh is used in intraperitoneal onlay position. The size of the mesh upholds the principle of maintaining an at least 5 cm overlap in all directions. There are several options to secure the mesh to the abdominal wall, including a combination of tacks and sutures, or securing the mesh to the abdominal wall with circumferential suture fixation. An absorbable suture (2–0) is placed around the mesh in a running fashion (**Figure 100.3d**). After completion of mesh fixation, the patient-side cart is undocked. The trocars are removed, and the pneumoperitoneum is released. The fascia at the 10 mm or larger trocar insertion site should be sutured to decrease the risk of future incisional hernia. Long-acting local anesthetic agent is injected into trocar sites for management of postoperative pain.

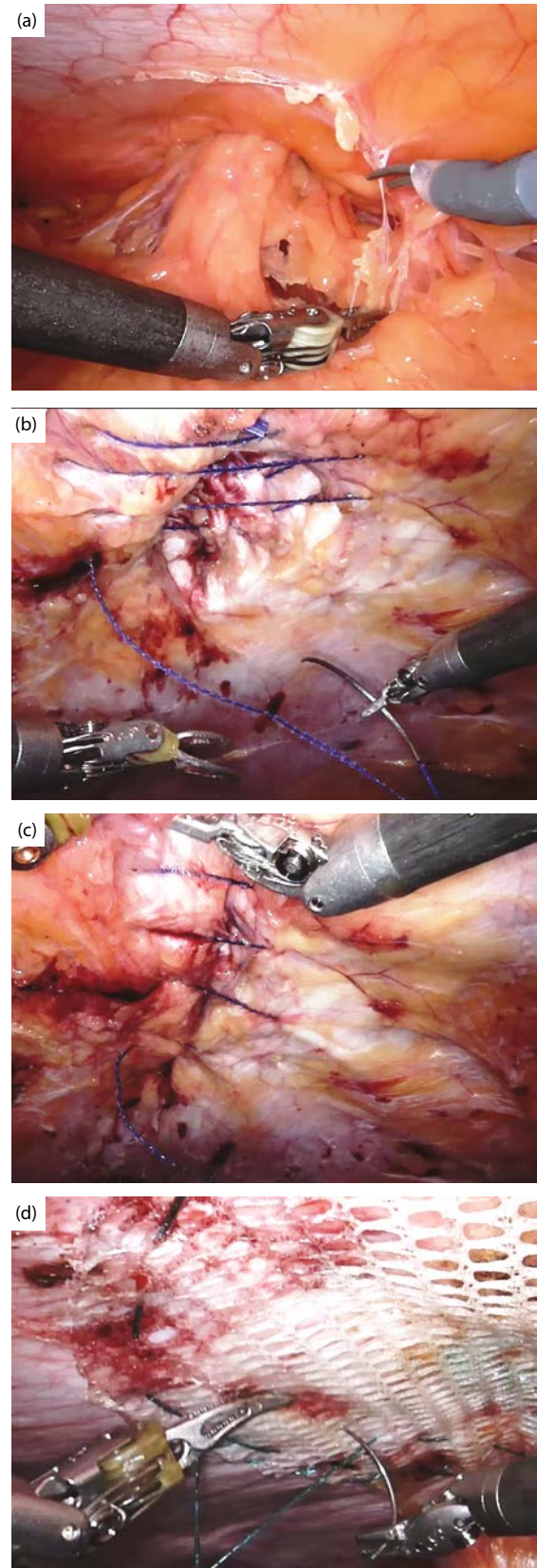


Figure 100.3 (a) Adhesiolysis. (b and c) Hernia defect closure in a shoelace fashion. (d) Mesh fixation with absorbable barbed suture.

ROBOTIC TRANSABDOMINAL PREPERITONEAL REPAIR

The potential complications due to adhesion are reduced to a minimum in the preperitoneal ventral hernia repair technique, since the peritoneal layer is located between the viscera and the mesh. Therefore, using coated mesh is not necessary as in the IPOM technique.¹² Instead, a low-cost option in preperitoneal repair with polypropylene mesh is suggested.¹³

Surgical technique

Patient preparation, positioning, initial access, trocar placement, and adhesiolysis are analogous to the previously described procedure.

PREPARATION OF PERITONEAL POCKET

Monopolar scissors and a bipolar Maryland forceps are used. The peritoneum is grasped and cut at least 5 cm from the defect on the side ipsilateral to the trocars to enter the preperitoneal space. Throughout the preparation of the peritoneal flap, the peritoneum should be tracked gently to avoid tearing. For this purpose, pressing on the peritoneal flap with the sponge, which is prepositioned in the operative field, helps in both controlling minor bleeding and minimizing the peritoneal tearing risk (**Figure 100.4a**). During the dissection of the peritoneum, which forms the inner layer of the hernia sac, separation of tissues without making peritoneal defects may not always be possible. In the situation of peritoneal integrity disruption, it should be repaired later by absorbable sutures. Preperitoneal dissection should extend at least 5 cm in all directions around the defect to provide adequate mesh layout. It should be kept in mind that the wide dissection of the preperitoneal space allows a large, mobile peritoneal flap for covering the mesh. One of the concerns in robotic TAPP is placing new mesh and keeping the old integrated mesh as part of the posterior layer as it is often fused and difficult to separate.

HERNIA DEFECT CLOSURE, MESH PLACEMENT, PERITONEAL FLAP CLOSURE

The hernia defect is closed with a barbed suture as described in IPOM technique after being measured by a ruler (**Figure 100.4b and c**). Once the rolled or folded noncoated mesh is introduced into intra-abdominal cavity through one of the trocar, it is unrolled or unfolded in the preperitoneal space without any wrinkles or folds. Then, it is circumferentially secured to posterior fascia with a barbed absorbable suture (2-0 V-Loc; Medtronic, New Haven, Connecticut).

After adequate mesh fixation and bleeding control are achieved, the next step is to close the peritoneal flap (**Figure 100.4d**). Rapidly absorbable barbed suture may be used for this purpose. At the end of the procedure, it should be checked that the entire mesh is covered with the peritoneal flap to protect the intra-abdominal structures from exposed mesh.

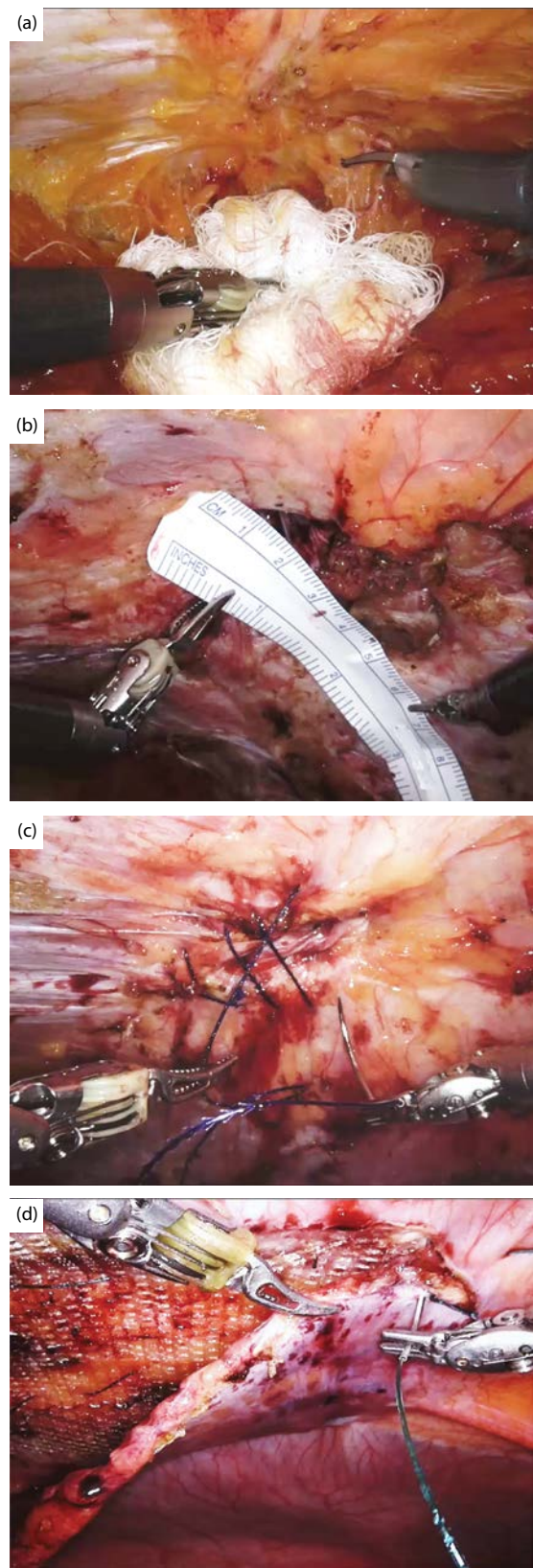


Figure 100.4 (a) Preperitoneal dissection and pressing on the peritoneal flap with the sponge. (b) The measurement of the hernia defect by a ruler. (c) The closure of the hernia defect. (d) The closure of peritoneal flap after mesh fixation.

ROBOTIC RETROMUSCULAR MESH REPAIR

The retrorectus repair, which was popularized by Rives-Stoppa-Wantz, is based on the theory that placement of mesh below the hernia defect and muscles will allow the abdominal pressure to keep the mesh in location.⁴ In this technique, the posterior rectus sheath is opened just off the linea alba, and the rectus muscle is dissected off the posterior rectus sheath. The posterior rectus sheath is then sewn together in the midline. Once the mesh is placed in this space, its contact with the abdominal structures is excluded. However, being a restricted sheath, the posterior rectus sheath limits the amount of mesh that can be placed laterally as the sheath ends.

Surgical technique

For patient preparation, standard principles that were mentioned at the beginning of this chapter are followed. Depending on hernia-related factors such as localization and size, it can be done either by a single- or double-docking method.

PATIENT POSITIONING, ACCESS, AND TROCAR POSITION FOR SINGLE-DOCKING RETROMUSCULAR REPAIR

The single-docking method can be applied in two different directions of dissection: from caudal to cranial or lateral to medial.

The craniocaudal approach can be suitable for upper midline hernias. For this purpose, the patient is positioned on the operating table in a slightly flexed Trendelenburg position to prevent robotic arms' collusion with the patient's pelvis and legs. Once pneumoperitoneum is obtained, three trocars are placed across the lower abdomen, following the same principles as previously described (**Figure 100.5a**).

In the lateral-to-medial approach, the dissection is planned from one lateral side to the other lateral side of the rectus sheath. After the placement of the initial trocar into the retromuscular plane in an ipsilateral semilunar line with the open technique, similar to the enhanced-view totally extraperitoneal (eTEP) hernia repair procedure,¹⁴ two trocars are aligned in the course of the ipsilateral border of the rectus sheath under the direct camera vision in accordance with the previously mentioned principles (**Figure 100.5b**).

RETROMUSCULAR DISSECTION, APPROXIMATION OF POSTERIOR RECTUS SHEATHS, AND MESH PLACEMENT

In the approach with a caudocranial direction, the content of the hernia sac is reduced and adhesiolysis is completed in order to assess the extent of the hernia defect. The dissection begins with a transverse incision, which is performed through the posterior rectus sheath to enter the retromuscular plane, at least 5 cm below the hernia defect. The incision is extended from the semilunar line on one side, continues to the retromuscular plane contralaterally, and ends at the opposite semilunar line. In order to enter the preperitoneal

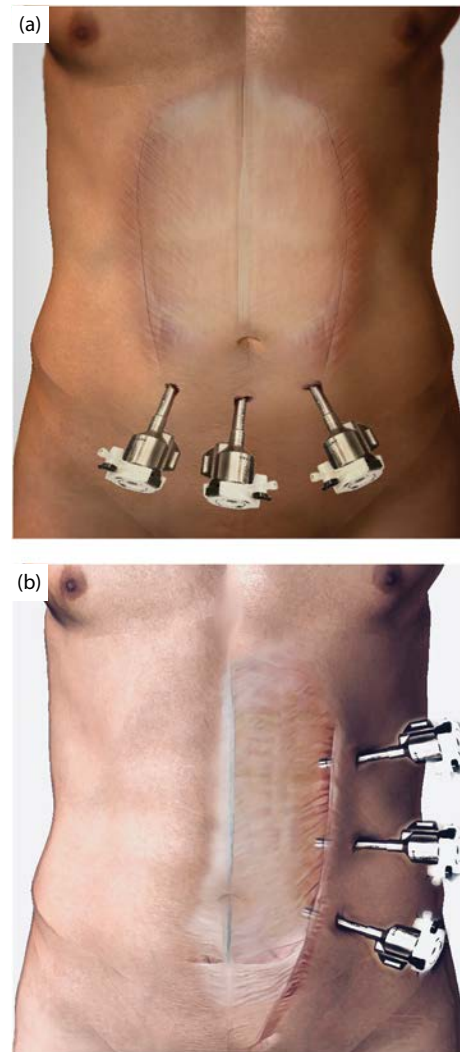


Figure 100.5 Trocar positioning: (a) caudocranial approach and (b) lateromedial approach (eTEP).

space behind the linea alba, the medial edges of both posterior sheaths are dissected along the midline (**Figure 100.6a**). Thus, the right retromuscular space and the left retromuscular space are merged to make an entire compartment. With proceeding dissection, the inferior edge of the hernia sac is encountered. It is not always possible to separate the hernia sac from the subcutaneous tissue. The integrity of the hernia sac should be ensured as far as possible. Dissection is extended at least 5 cm above the hernia sac. If the integrity of the newly developed pocket is deteriorated at any place except the midline, which will be closed later, these holes should be closed with absorbable suture.

In the medial direction approach, after completion of ipsilateral retrorectus dissection, the medial edge of the rectus sheath is incised to reach the contralateral rectus sheath, provided that the peritoneum, which is posterior to the linea alba, is kept intact (**Figure 100.6b**). After completion of retromuscular dissection on the contralateral side, the posterior sheaths are not approximated and only the peritoneal entry

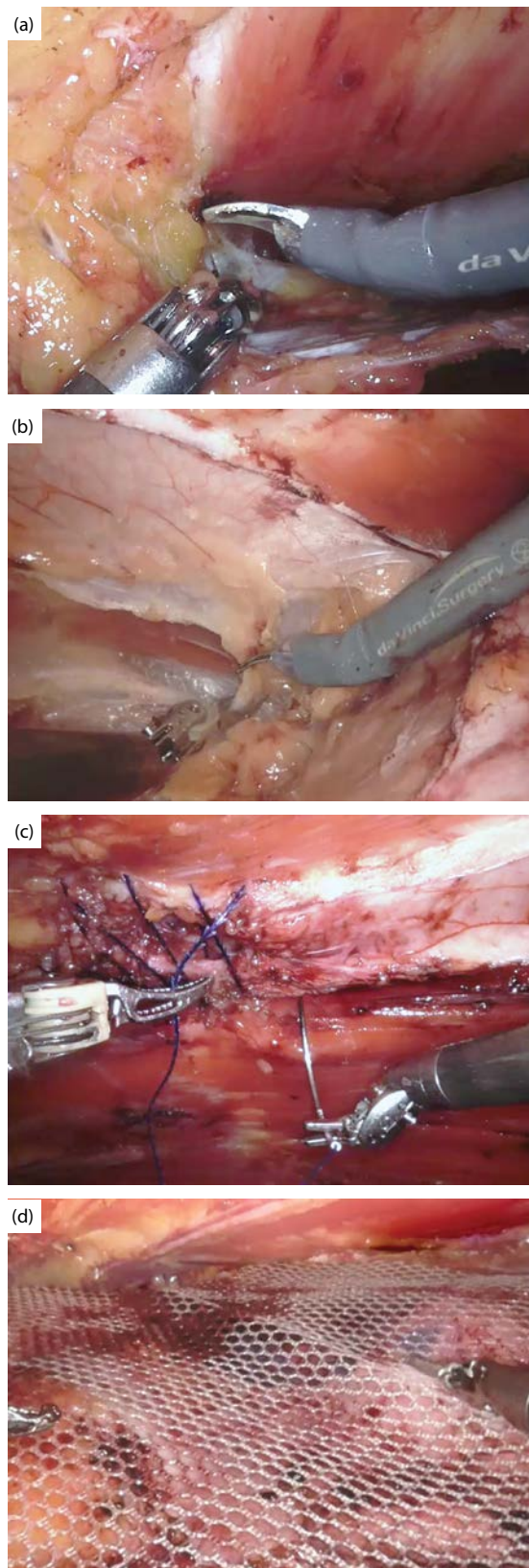


Figure 100.6 (a) Dissection of medial edge of rectus sheath in caudocranial approach. (b) Dissection of contralateral medial edge of rectus sheath in lateromedial approach. (c) The closure of hernia defect. (d) Mesh placement.

and hernia sac are closed using a 2–0 absorbable barbed suture. The defect is then closed using an absorbable barbed suture in a shoelace fashion, which was previously described (Figure 100.6c). A polypropylene mesh is shaped to occupy the entire retromuscular dissected area and is placed against the anterior abdominal wall (Figure 100.6d). The mesh is secured with a few interrupted absorbable sutures. Minimal fixation is generally enough, since physiological intra-abdominal pressure will aid in maintaining the mesh in position. If there is a necessity for greater medialization of the posterior rectus sheath for approximation, proceeding to a robotic TAR technique would be a suitable option.

ROBOTIC TRANSVERSUS ABDOMINIS RELEASE

The theory of the TAR technique is based on the posterior component separation technique (PCST), which was first described by Carbonell et al.¹⁵ The aim of this technique is to extend the retrorectus dissection plane to outside of the rectus sheath in order to obtain more space for larger meshes. However, the neurovascular bundles that supply the rectus abdominis muscles might be damaged when the dissection proceeds laterally between the internal oblique and the transversus abdominis muscle in this technique. Moreover, the amount of myofascial medialization might be limited to restore the posterior layer. These are accepted as potential drawbacks. In the TAR technique, which was popularized by Novitsky,¹⁶ the neurovascular bundles are protected, since the dissection plane proceeds lateral to the semilunar line in the preperitoneal space. Furthermore, the TAR technique allows for significant posterior rectus fascia advancement.

Surgical technique

Patients who have midabdominal wall defects (7–18 cm) or lateral defects such as parastomal hernia are good candidates for robotic TAR.

TROCAR POSITION, ADHESIOLYSIS, POSTERIOR SHEATH MOBILIZATION, HERNIA SAC DISSECTION

The patient is positioned supine, arms out, and with the bed flexed slightly. Once pneumoperitoneum is obtained, three of six trocars are placed along the anterior axillary line as described in the rIPOM technique (Figure 100.7). After exposing the hernia defect with any necessary adhesiolysis and hernia reduction as described before, the retromuscular dissection is initiated from the contralateral medial edge of rectus sheath (Figure 100.8a) and is carried out laterally to the semilunar line, superiorly to the costal margin, and inferiorly toward the pubic tubercle.

TRANSVERSUS ABDOMINIS RELEASE, PREPARATION AND INITIAL FIXATION OF THE MESH, CONTRALATERAL TROCAR PLACEMENT

When the lateral border of the rectus sheath is reached, transversus abdominis fascia and muscle are begun to be

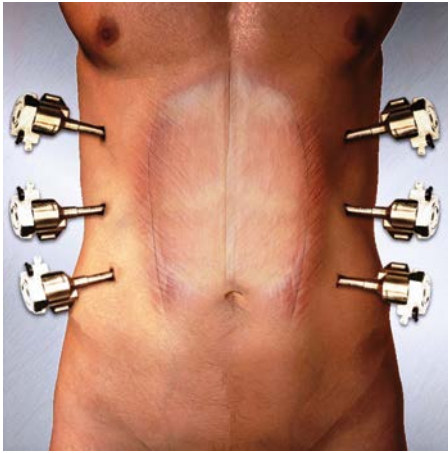


Figure 100.7 Trocar positioning for robotic TAR technique.

divided from ~1 cm medial of the lateral border of the rectus sheath to enter the preperitoneal plane, to keep neurovascular bundles intact. Beginning the initial release of the transversus abdominis fascia at the lateral arcuate line can facilitate finding the correct dissection plane (**Figure 100.8b**). Typically, continuing the bottom-to-up dissection, fibers of transversus abdominis, which can be easily recognized, are encountered. For the upper abdominal level, incision of the posterior lamella of the internal oblique aponeurosis exposes the medial fibers of the transversus abdominis muscle on the posterior rectus sheath. Then, these fibers are divided from the top to the bottom extent of posterior sheath mobilization (**Figure 100.8c**). Preperitoneal dissection is extended laterally to approximately the midaxillary line.

Subsequently, dimensions of dissection are measured as longitudinal and mediolateral in order to choose an appropriately sized mesh that will be utilized for covering the retromuscular area. The mesh is shaped and is rolled along its longitudinal axis. In order to ensure that its furled form is maintained, one or two sutures, which will be cut before the deployment of the mesh, are placed. The mesh is secured with a few absorbable sutures along the posterolateral abdominal wall after introducing it into the abdominal cavity (**Figure 100.8d**).

Then three trocars are inserted along the contralateral anterior axillary line under direct camera vision, so they are placed above the posterior layer as well as the mesh.

CONTRALATERAL DISSECTION, APPROXIMATION OF THE POSTERIOR SHEATHS, CLOSURE OF THE DEFECT, AND DEPLOYMENT OF MESH

The robot is redocked on the contralateral side. Contralateral retrorectus dissection and TAR are performed as described (**Figure 100.9a**). At the end of the preperitoneal dissection, the initially placed trocars are brought into the preperitoneal space. Adequate overlap of the hernia defect and any previous midline incision should be provided with retroxiphoidal

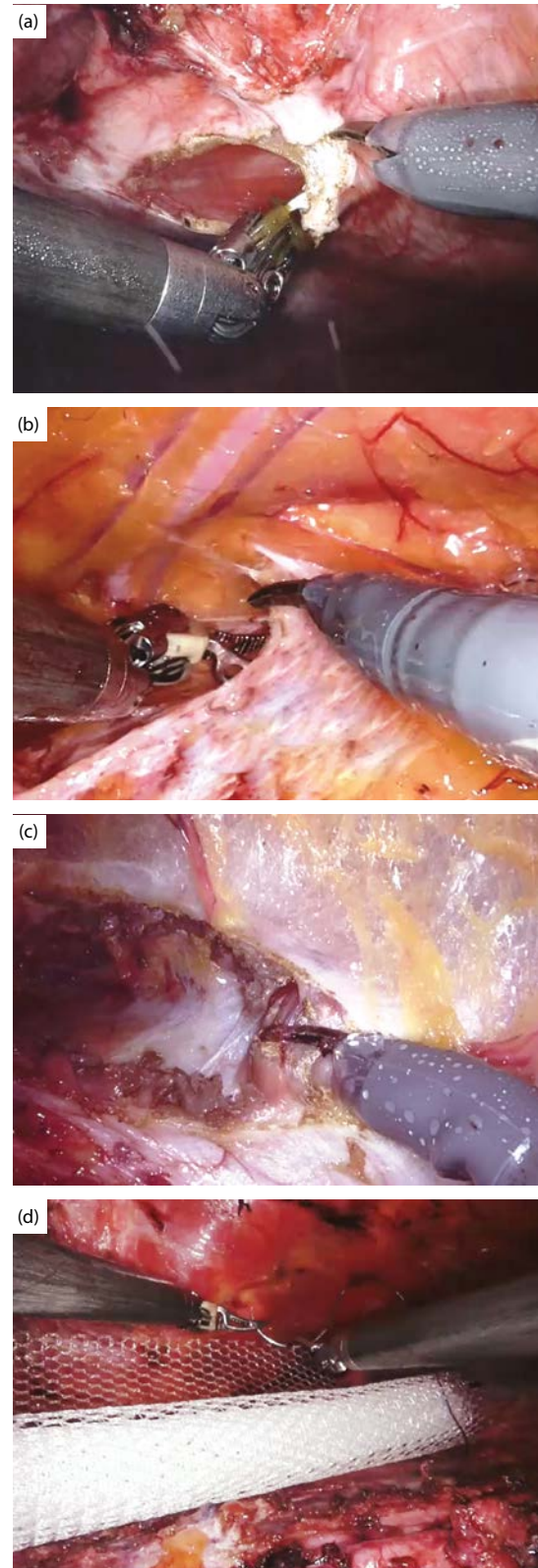


Figure 100.8 (a) Contralateral posterior rectus sheath mobilization. (b) Beginning of the initial release of transversus abdominis fascia at the lateral border of the arcuate line. (c) Dissection of transversus abdominis fibers. (d) Initial mesh fixation at the contralateral side.

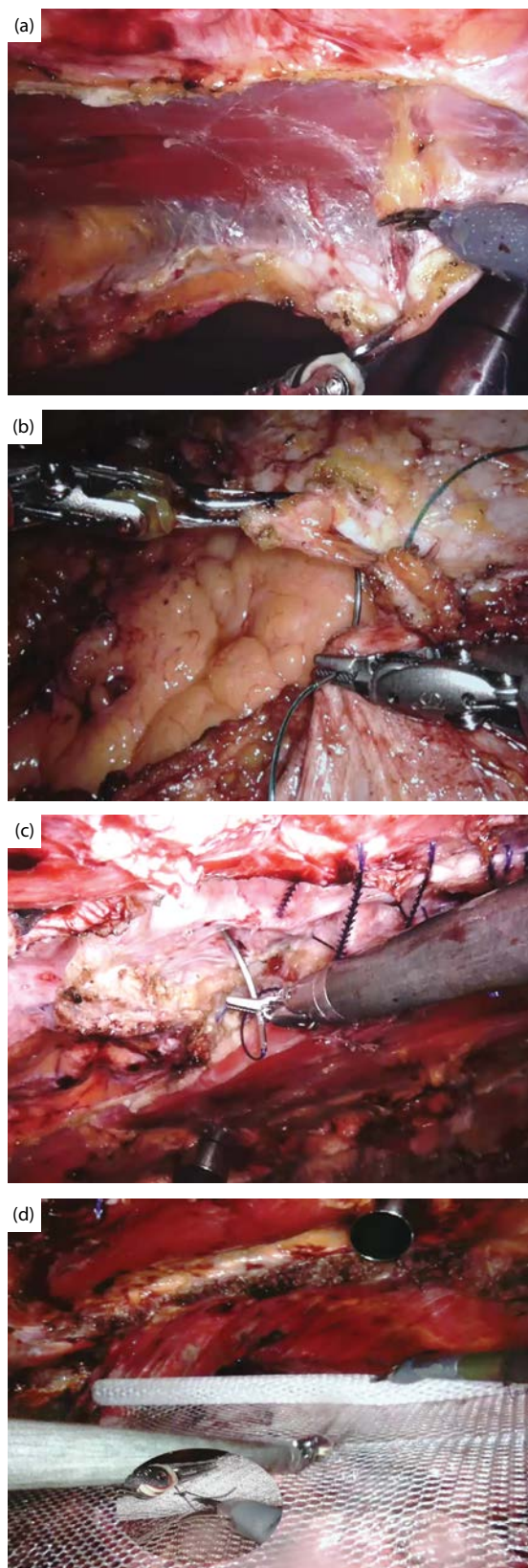


Figure 100.9 (a) Contralateral retrorectus dissection after redocking. (b) The approximation of the posterior rectus sheath. (c) Closure of the hernia defect. (d) Mesh deployment after cutting the stitch that maintains the furred form of the mesh.

or retropubic dissection. It is enough for sufficient TAR dissection to complete it when the two flaps of the posterior sheath lie inferiorly over the viscera. The midline posterior sheath is closed using a 2–0 absorbable barbed suture in a running fashion (**Figure 100.9b**). The hernia defect is then closed using an absorbable barbed suture (**Figure 100.9c**). The anterior fascia is approximated with barbed suture. Any peritoneal defects should be closed with absorbable suture. All of these closures are facilitated by reducing the level of pneumoperitoneum to between 6 and 8 mmHg.

The previously placed mesh is unfurled, is deployed without any wrinkles, and is secured to the contralateral abdominal wall with absorbable sutures (**Figure 100.9d**). Pneumoperitoneum is released, and trocars are removed. There is no need to close the trocar sites, as each is covered by the mesh. A placement of a drain is generally not necessary.

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Laparoscopic repair of recurrent inguinal hernia

BRANDICE DURKAN AND EDWARD H. PHILLIPS

INTRODUCTION

Inguinal hernioplasty is the most common surgical procedure performed by general surgeons. Surgeons want to use a repair that is easy to perform, painless, and secure. The widely used nonmesh modified Bassini and the nonmesh Shouldice repairs have been largely replaced by tension-free onlay mesh hernioplasty because of less pain, ease of performance, and a low recurrence rate. However, recurrence remains a problem. Large database studies from Denmark and Sweden show that reoperation rates after primary mesh repair range from 3.1% to 17%.¹⁻⁴

With the introduction of laparoscopic hernia techniques in the early 1990s, there was hope that recurrence rates would be reduced. However, studies demonstrate that the anterior tension-free mesh and laparoscopic approaches are equal in terms of recurrence in primary inguinal hernias in 5 years follow-up.⁵⁻⁷ Preventing a recurrence after repair of a recurrent hernia is more challenging based on the rate of a second recurrence, which is as high as 33%.⁸

SELECTING A TECHNIQUE TO REPAIR A RECURRENT HERNIA

The main considerations in choosing an approach include the following:

1. Safety/ease of performance
2. Re-recurrence rate
3. Chronic pain incidence
4. Time to return to work/usual activities
5. Predicted cosmetic outcome

First, does the hernia need to be repaired? A prospective randomized multicenter trial of watchful waiting versus Lichtenstein repair studied this question.⁹ Forty-three patients were randomized. At 2 years, only 15 patients (35%) went on to

surgical intervention when symptoms dictated. There were no adverse outcomes associated with delaying the repair.¹⁰

Once the decision is made to repair a recurrent hernia, the surgical approach depends on the patient's symptoms, the type of initial repair, and the experience of the operator. Initial repairs include primary tissue repair (Bassini, McVay, or Shouldice), anterior mesh repair (Lichtenstein-type onlay patch, plug and patch, or Prolene Hernia System), posterior mesh repair (Read, Rives, Stoppa, or Kugel), or laparoscopic (transabdominal preperitoneal [TAPP] or totally extraperitoneal [TEP]). In general, if the initial repair was performed anteriorly, a retroperitoneal repair by laparoscopy or open Cheate-Henry approach to the preperitoneum is preferable to avoid scar tissue and distorted anatomy. If the repair was performed posteriorly, an anterior repair is preferable.

LAPAROSCOPIC TECHNIQUES

Laparoscopic approaches result in less postoperative and chronic pain, shorter hospital stays, and increased patient satisfaction. However, technical difficulty, operative time, and direct costs are increased.¹¹⁻¹⁷

Transabdominal preperitoneal

The TAPP approach places mesh in the preperitoneal space with an incision in the peritoneum. Mesh implantation as an underlay repair results in a tension-free repair, thereby reducing pain and, theoretically, recurrence.^{18,19} Single-institution studies demonstrate re-recurrence rates of 0.5%–3% when TAPP is performed for recurrence after a prior anterior repair. The Danish Hernia Database demonstrated a re-recurrence rate of 1.3% for TAPP versus 11.3% for Lichtenstein approach.⁴ Mahon et al. found TAP resulted in significantly less early postoperative pain and significantly

less chronic pain compared with open mesh repair.²⁰ All studies consistently show a significant learning curve associated with the TAPP repair. TAPP for recurrent hernia should only be attempted by surgeons who have experience with the technique.^{1,2,4,20–26} There are little data on TAPP repair of a previous laparoscopic repair, as it is infrequently performed unless the prior mesh needs to be removed, since the peritoneum becomes adherent to the mesh.

Totally extraperitoneal

The TEP repair places mesh in the preperitoneal space without an incision in the peritoneum. Like TAPP, the TEP approach is difficult, if not impossible, following prior preperitoneal mesh placement or other preperitoneal surgeries like a radical open prostatectomy. One prospective randomized study with a subset analysis of laparoscopy for recurrent hernia and one prospective controlled, non-randomized study looking at TEP versus open repair for recurrence support the use of TEP for hernia recurrence of a previous anterior repair.^{23,27} Incidence of re-recurrence after TEP varies from 0% to 20%, but most series report similar or improved recurrence rates compared with open re-repair.^{28,29} Examples include one large single-institution study with a re-recurrence rate of 0.3% after TEP.²⁵ Another group had a reoperation rate of 1.3% after TEP for recurrence; this was in contrast to reoperation rates for open tension-free mesh repair of 3.2% and nonmesh repairs of 6.7%.¹

Studies show that patients who undergo laparoscopic surgery for recurrence have decreased postoperative pain, earlier return to normal activities, and fewer wound and mesh infections.^{5,20–23,31–34} There are limited data comparing TAPP and TEP directly. The literature documents a steep learning curve, and only surgeons with experience should approach a recurrent hernia with a TEP technique.^{1,4,21,24–26,32–34,36–39}

Prior anterior repair

If the initial repair did not use mesh, either an anterior or posterior approach is acceptable, though a posterior laparoscopic repair avoids the difficulty of dissection of prior scar tissue and altered anatomy. If mesh was used and does not need to be removed, a laparoscopic repair should be used, as the dissection of prior mesh adds to the complexity of an anterior approach. The European Hernia Society recommendations for recurrent hernia are the following: If the previous repair was through an anterior route, consider open preperitoneal mesh or laparoscopic approach (if expertise is present for laparoscopic repair: TEP rather than TAPP).

Prior posterior repair

If the previous repair was through a posterior route, an anterior mesh repair is preferable.⁴⁰

Prior anterior and posterior repair

If the patient has had a recurrence following a combined anterior-posterior approach, an open Stoppa-like repair is preferred unless the prior repair did not use mesh. In that situation, an anterior approach with a mesh repair can be performed.

CHALLENGES

Incarceration with or without bowel compromise or infection

Laparoscopic repair of an incarcerated hernia may be safely attempted; however, there is a high conversion rate to the open approach. There are minimal data to support a laparoscopic approach to the recurrent incarcerated hernia, but it can be attempted in experienced hands.³⁰ An advantage of the laparoscopic approach is the ability to completely evaluate bowel viability, clamp the bowel prior to reduction, and even perform a laparoscopic bowel resection and anastomosis. Even if a TEP approach is used to repair the hernia, the umbilical port may be placed intraperitoneally to view the entirety of the bowel prior to or after the repair.

A TAPP or TEP should not be completed with mesh when there is necrotic bowel or peritonitis seen during laparoscopy. Placement of mesh in this setting risks mesh infection and the associated complications of fistula, chronic draining sinus, and an increased recurrence rate. With evidence of infection in the space, a myofascial Bassini or Shouldice repair is recommended (if femoral, a McVay repair).

Risk of testicular injury

Testicular atrophy following repair of recurrent inguinal hernia is an important outcome measure that is not well addressed in current literature. It is higher when a combined procedure such as hydrocelectomy is performed. Thorough review of the original operative report aids in decision-making. Although seldom necessary, orchiectomy should be discussed preoperatively. A laparoscopic repair of a recurrence after an anterior repair significantly decreases risk of testicular ischemia through avoidance of cord dissection.³⁵

Recurrence with pain from mesh or nerves

If the patient is experiencing symptoms from a “meshoma,” or nerve pain that requires mesh removal or neurolysis/neurectomy, use the approach that was used to place the mesh originally. If nerves need to be cut, an anterior approach is usually preferable unless the operator has experience to perform laparoscopic or open retroperitoneal neurectomy.

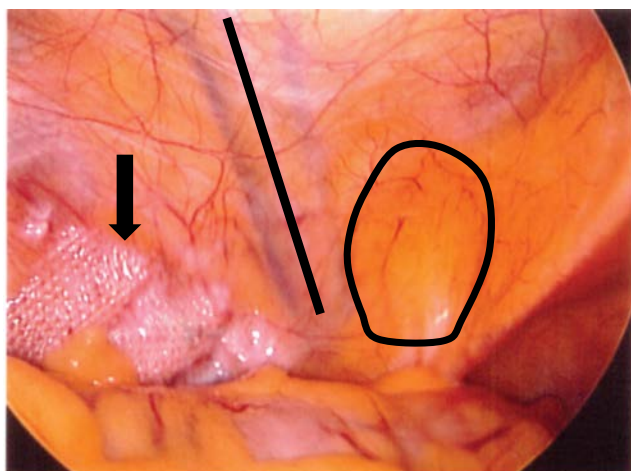


Figure 101.1 Intraoperative view of a recurrent direct inguinal hernia. The inferior epigastric vessels are marked with a line. The site of direct recurrence is outlined with a circle. The previously placed mesh (arrow) is densely adherent to the peritoneum, which makes dissection of the preperitoneum a challenge.

When performing a TAPP or TEP repair of a recurrence following a preperitoneal open mesh repair (plug and patch, Kugel, etc.), old mesh will be encountered (**Figure 101.1**). The prior mesh may be amenable to trimming with scissor, ultrasound scalpel, or electrocautery. However, care must be taken to avoid injury to adjacent structures such as bladder or femoral/iliac vasculature. Peritoneum adherent to the prior mesh



Figure 101.2 The completed TEP laparoscopic repair. The defect is completely covered. There are no peritoneal suture lines with TEP that come into contact with intra-abdominal contents.

may preclude preperitoneal mesh placement. If performing a laparoscopic repair following prior laparoscopic initial surgery, it may be best to leave the original mesh in place and add a new mesh over any defects resulting from folded, contracted, or misplaced mesh (**Figure 101.2**). In these settings, it is wise to educate, inform and consent the patient for an anterior approach should that become necessary.

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Laparoscopic repair of sports hernia

L. MICHAEL BRUNT

INTRODUCTION

Groin injuries are a common problem in sports, and in recent years increased attention has been directed toward the condition popularly known as a “sports hernia.” The term *sports hernia* is a misnomer in the sense that this condition is not a true herniation. As a result, alternative terms have been recommended that better reflect the underlying nature of this problem; these include athletic pubalgia, inguinal disruption, and abdominal core injury. Although surgery for athletes with sports hernia has become commonplace only over the last 15 years, this entity was recognized in the early 1980s as one that could prematurely end an athlete’s career. For physicians who are asked to evaluate an athlete for possible sports hernia, it is important to understand the various causes of athletic groin pain and to have a systematic approach to the diagnosis and management of these individuals.¹ In this chapter, the author’s approach to the diagnostic evaluation and management of athletic groin pain is discussed, including both laparoscopic and open approaches.

BACKGROUND

Groin injuries are most common in sports in which there are frequent repetitive movements at high speed, such as cutting, turning, sprinting, and kicking motions. Sports that are particularly vulnerable to these types of injuries include soccer, football, and ice hockey. The reported incidence has ranged from 5% to 28% in soccer players² and 6% to 15% in elite ice hockey players.^{3,4} Unlike a lot of sports-related injuries, athletic groin injuries do not necessarily result from direct physical contact. Most of these injuries are soft tissue in nature, and the adductor muscle group is the most commonly injured site.

Engrebetson and colleagues⁵ analyzed risk factors for groin injuries in a study of male soccer players in Norway. They

found that the incidence of injury was 0.6 per 1,000 player hours. Multivariate analysis showed that a previous history of an acute groin injury or weak adductor muscles on clinical evaluation were associated with an increased risk of groin injury. Another study by Tyler et al.⁶ looked at hip strength and flexibility in one National Hockey League team prospectively. They found that the adductor-to-abductor strength ratio was greatly decreased on the side of the injury. Most importantly, a program of adductor strengthening reduced the incidence from 3.2 per 1,000 game exposures to 0.71.

DIFFERENTIAL DIAGNOSIS

The evaluation and management of athletic groin injuries can be challenging for many reasons: The regional anatomy is complex, there are numerous potential causes, and they can be difficult to diagnose and treat accurately. Fortunately, most athletic groin injuries resolve with conservative management and infrequently require surgical intervention. The differential diagnosis of athletic groin injuries is broad and includes muscular strains that may involve the rectus abdominal, obliques, iliopsoas, hip flexors, and adductor muscle groups. Pelvis-related injuries such as osteitis pubis and stress fractures also present as groin or pubic pain, and hip injuries, including labral tears, femoroacetabular impingement, and even hip arthritis, are also in the differential. True inguinal hernia is an infrequent cause of groin pain in the athlete but may occasionally be present either as a symptomatic or an incidental finding. Finally, one must consider the potential for nonathletic causes of groin pain such as gynecologic problems in young women and gastrointestinal, urologic, and other sources.

The regional anatomy of the groin is among the most complex biomechanically in the entire musculoskeletal system. A representation of the anatomy is shown in [Figure 102.1](#) schematically. It is important that physicians and athletic trainers

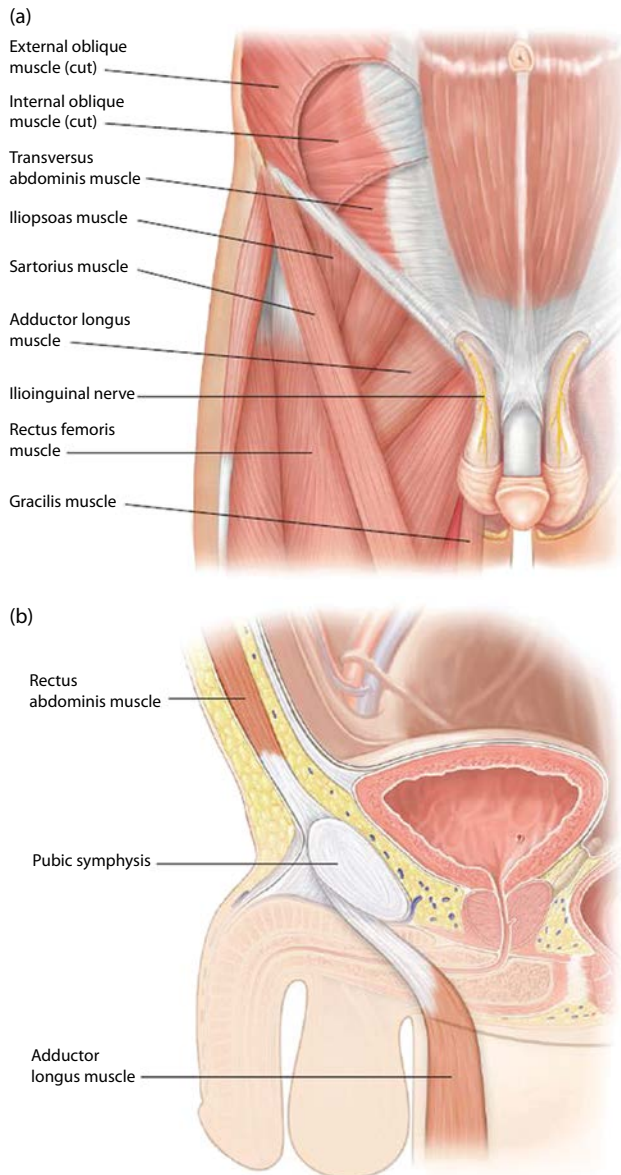


Figure 102.1 Anatomy of the pelvic region musculature: (a) standard view and (b) sagittal view. Note how the rectus and adductor aponeurosis wrap around the pubis on the sagittal view; this is often the site of tears in athletic pubalgia-type injuries. (Reproduced with permission from Brunt LM. Sports Hernia. In: Jones DB (ed) *Masters Techniques in Hernia Surgery*. Lippincott, Wilkins, Williams; 2013:219–29.³⁵)

who care for athletes understand the basic anatomy of the musculoskeletal system around the pelvis in order to accurately differentiate and diagnosis the various injuries. The evaluation should begin with a detailed history and physical examination. Important aspects of the history include the circumstances around the onset of symptoms, location of the pain, and whether it radiates. Does the pain get better with rest? What activities precipitate symptoms? Were there potentially predisposing factors, such as a prior injury or a recent change in training regimen? As previously noted,

adductor strains are very common in sports. Acute adductor injuries often are associated with a history of a sudden injury or even a pop or pull in the groin. These usually resolve with conservative management, even if there is a complete disruption or detachment of the adductor longus from the pubis. Treatment should consist of rest, ice, compression, nonsteroidal anti-inflammatory agents for pain control, and thermal modalities such as ultrasound and e-stimulation. Once the acute symptoms have settled, progressive range of motion exercise, balance training, and a graduated strengthening program followed by return to sports-specific function activities should be undertaken. The amount of time that a player may miss with an adductor injury may range from a few days to 5–6 weeks depending on the extent of the injury.

Sports hernia represents a subset of athletic groin injuries in which there is chronic exertional inguinal or lower abdominal pain that fails to resolve with conservative management. The pain typically occurs during the extremes of exertion and is absent at rest or with normal light activities. Athletes often complain of pain with sudden starts, cutting or turning movements, and kicking motions. Because the players lose some of their ability to suddenly accelerate, they can be challenged to continue to compete at the elite level. Additional symptoms may include pain with coughing or sneezing or getting in and out of bed or a car. It is not unusual to have associated adductor symptoms, which can occur in up to 50% of athletes. The onset is often insidious and without a clear-cut precipitating event.

DIAGNOSIS AND EXAMINATION

The classic finding on physical exam in an athlete with a sports hernia is tenderness at the distal lateral rectus/medial inguinal canal junction. There may also be a dilated external inguinal ring and a palpable gap or defect over the inguinal floor without an associated bulging or protrusion. Pain with a resisted sit-up or resisted trunk rotation is also commonly observed. There may also be pain on the abdominal side of the pubis with resisted straight leg raising or hip flexion and resisted adduction.

Meyers⁷ has described 17 different clinical entities of athletic pubalgia, of which approximately 90% consist of either a pure abdominal injury, a pure adductor injury, or a combination of the two. Various mechanisms have been proposed to explain the pathophysiology and pain, and these include, principally, (1) the presence of an injury to the rectus tendon or aponeurosis injury or to the rectus/adductor aponeurosis complex, which can be seen on magnetic resonance imaging (MRI)⁸ or (2) weakness of the posterior abdominal wall and inguinal floor or “inguinal disruption”⁹ (Figure 102.2). Some authors have also postulated a component of inguinal or genital neuropathy as a source of the pain, but that mechanism is not widely accepted.

In most centers, the preferred imaging modality is a high-resolution pelvic MRI, which should include axial, coronal, and oblique sequences.^{10,11} Findings on MRI

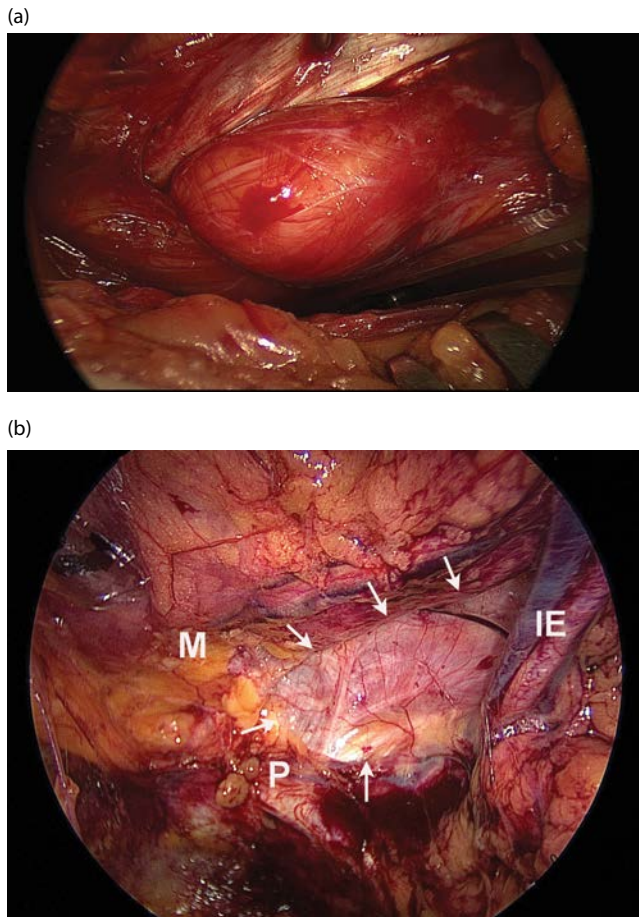


Figure 102.2 Operative view of inguinal floor in abdominal core sports injury. (a) Open view of posterior inguinal disruption. (b) Laparoscopic view of posterior inguinal disruption, right side (arrows). (IE, inferior epigastrics; M, midline; P, pubis.) Arrows point to the area of disruption of the posterior inguinal floor.

associated with sports hernia include tears of the combined rectus-adductor aponeurosis or isolated rectus or adductor tears of varying degrees (Figures 102.3 and 102.4), parasympyseal edema, or a secondary cleft (Figure 102.5). MRI can also be useful for the evaluation of associated hip pathology. Computed tomography is not generally indicated for the evaluation of athletic groin pain, because it fails to show the musculotendinous details and is mainly limited to patients with suspected stress fractures. Some groups use dynamic ultrasound to look for bulging in the posterior inguinal floor.¹² This modality is highly operator dependent and does not allow assessment of the other bony and soft tissue structures (e.g., adductors) around the pelvis.

INDICATIONS FOR SURGICAL MANAGEMENT

Indications for surgery are symptoms that limit athletic performance, failure of a period of conservative therapy,



Figure 102.3 Pelvic MRI images of left rectus tear. Shown are (a) axial and (b) sagittal views. The area of separation appears as a white line on the images (circled in axial view, arrow in sagittal view).

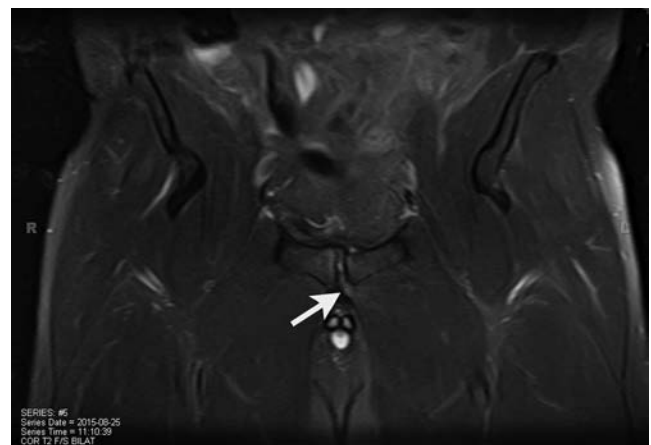


Figure 102.4 MRI of left adductor tear (arrow). The tear extends into the symphysis with evidence of a cleft.

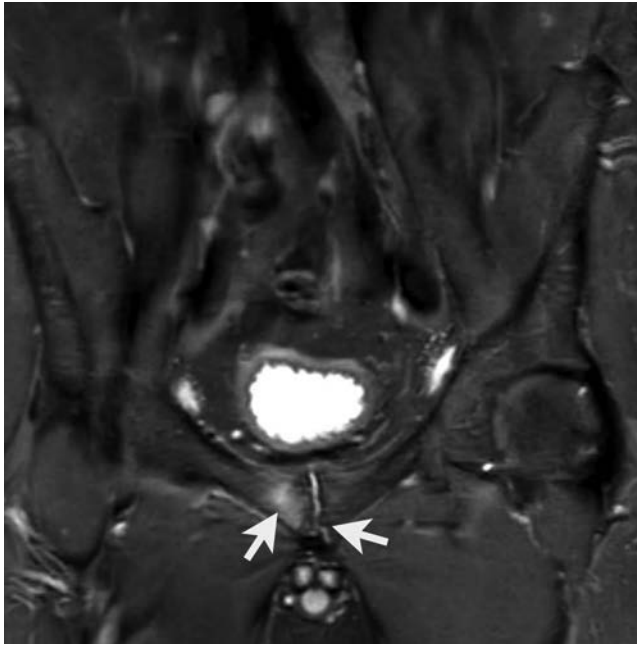


Figure 102.5 Pelvic MRI that shows right parasymphseal edema (right arrow) and a tear extending into the left side (arrow).

usually a minimum of 6–8 weeks, and the exclusion of other diagnoses that would explain the athlete's groin pain.¹ Most commonly the other associated pathology that needs to be considered is hip related (labral tear and impingement), and this may coexist with sports hernia pubalgia.

Two prospective randomized trials have evaluated surgical management versus conservative treatment for this condition.^{13,14} Both of these studies have shown higher rates of return to sport in an unrestricted and pain-free fashion than conservative management. In the more recent study, Pajannan and colleagues¹⁴ randomized 60 patients to operative conservative management. At 3 months, 90% of patients in the operative group had returned to sport compared to only 27% in the conservatively managed group.

The return to sport rates at 12 months were 97% for operative management and 50% for conservative management. Additionally, after 6 months, 7 of the 30 athletes in the conservative group crossed over and underwent surgery. These studies strongly support the role of surgical intervention in appropriately selected patients.

SURGICAL APPROACHES

Various surgical approaches have been advocated for this condition and are listed in [Table 102.1](#). Briefly, the primary pelvic floor as described by Meyers¹⁵ consists of a primary sutured repair of the inguinal floor and distal rectus and in selected athletes is done in conjunction with an adductor release. Muschawek and Berger¹⁶ described a minimal repair technique in which only the damaged portion of the inguinal floor is opened. The floor is then resutured with a continuous running suture with overlapping layers somewhat analogous to the Shouldice approach. An open anterior mesh repair has been advocated by many groups and has been the preferred approach of the author for this condition.^{17–20} The goal of this repair is to provide support and stability across the posterior inguinal floor and lower rectus insertion. A laparoscopic posterior mesh repair has been used increasingly for sports hernia repair, and several groups have reported excellent results with this approach. More recently, a laparoscopic posterior mesh repair accompanied by release of the inguinal ligament has been advocated by Lloyd.²¹

Laparoscopic repair of sports hernia was first reported in 1997 and can be accomplished by either a transabdominal preperitoneal (TAPP) or total extraperitoneal (TEP) approach.^{22,23} Most reported series have used the TEP approach, which is also the author's preferred laparoscopic method. The operation is basically the same as a standard TEP inguinal hernia repair. Briefly, access is carried out with a 2 cm infraumbilical incision, and the posterior rectus sheath is accessed on the side of the planned repair. The preperitoneal space is then developed with a balloon dissector under direct laparoscopic visualization. The space is dissected out to expose the entire posterior inguinal floor on the side of injury (or both sides for

Table 102.1 Published results of laparoscopic repair of sports hernia

Author/year	n	Approach	Return to sport (%)	Mean follow-up
Ingoldby ²³	14	TAPP	93	–
Srinivasan ²⁶	15	TEP	87	46 months
Evans ²⁷	287	TAPP	95	3–48 months
Paajanen ²⁸	41		95	48 months
Kluin ²⁹	14	TAPP and TEP	93	3 months
Genitsaris ³⁰	131	TAPP	99	60 months
van Veen ³¹	55	TEP	91	3 months
Ziprin ³²	17	TAPP	94	23 weeks
Lloyd ²¹	48	TAPP + inguinal ligament release	92	
Bernhardt ³³	47	TAPP	?	?
Rossidis ³⁴	54	TEP + adductor tenotomy	100	18 months

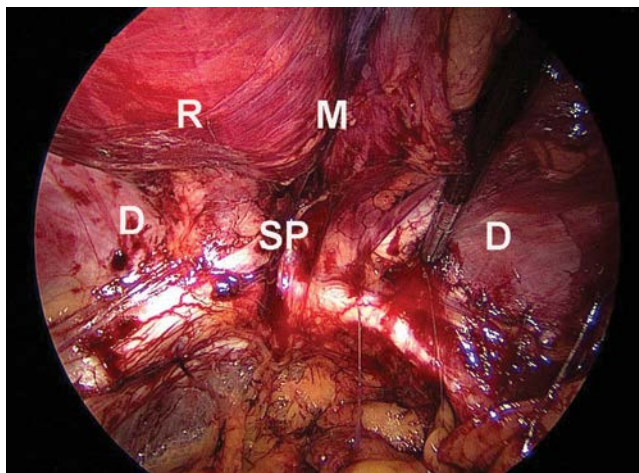


Figure 102.6 Laparoscopic view of dissected inguinal floor. Shown are the midline (M), posterior rectus muscles (R), direct spaces (D), and symphysis pubis (SP).

bilateral injuries) from the midline along Cooper's ligament to lateral to the indirect space (**Figure 102.6**). The peritoneum is dissected for 5–6 cm proximal to the internal ring to prevent the future development of an indirect hernia. A lightweight mesh is then placed to cover the entire inguinal floor and distal rectus extending from the midline to lateral to the internal ring (**Figure 102.7**). Absorbable fixation is used to secure the mesh with a tacking device.

The most common finding at laparoscopy, as with the open approach, is weakness of the posterior inguinal floor or direct space, but tears at the rectus insertion and/or thinning of the rectus may be seen in some athletes (**Figure 102.8**). Wikiel and Eid²⁴ recently reported on laparoscopic

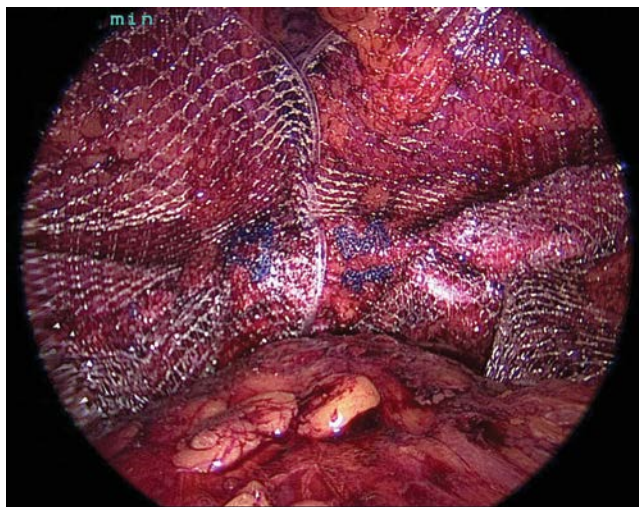


Figure 102.7 Bilateral tension-free mesh repair of disrupted inguinal floors, total extraperitoneal approach. The mesh overlaps in the midline and is secured with an absorbable tacking device.

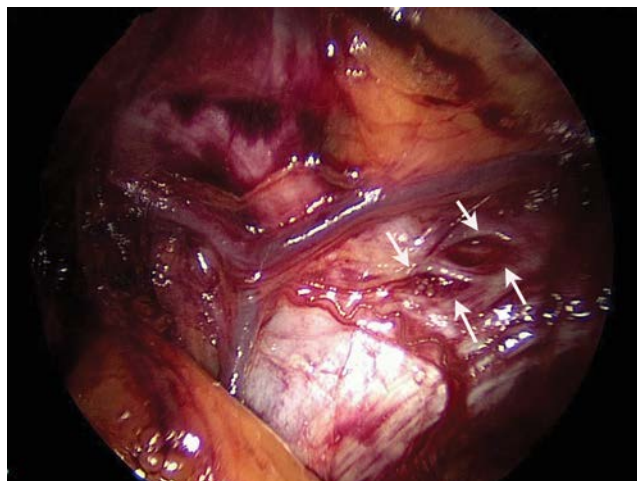


Figure 102.8 Laparoscopic view that shows small tears (arrows) that are seen in the distal rectus left side.

findings in 40 athletes and noted small bilateral indirect defects in 85% of their athletes. A direct hernia was present in only one case, and there were five athletes (12.5%) who had femoral hernias. These findings are not consistent with what has been reported by other groups; while the reasons for this are unclear, one possible explanation is that it may have been due to a high percentage of recreational athletes (72.5%) in their series.

The authors utilized an open approach for most athletes with sports hernia pubalgia.^{1,25} This procedure is done under local anesthesia with sedation and is carried out via a standard inguinal incision. There is often marked attenuation in the external oblique aponeurosis (**Figure 102.9**), an aspect that is not addressed by the laparoscopic repair, although the importance of this finding in the pathophysiology of athletic groin pain is unclear. The inguinal floor is repaired using a lightweight mesh placed in a tension-free fashion. The mesh is sutured to the transversalis aponeurosis and

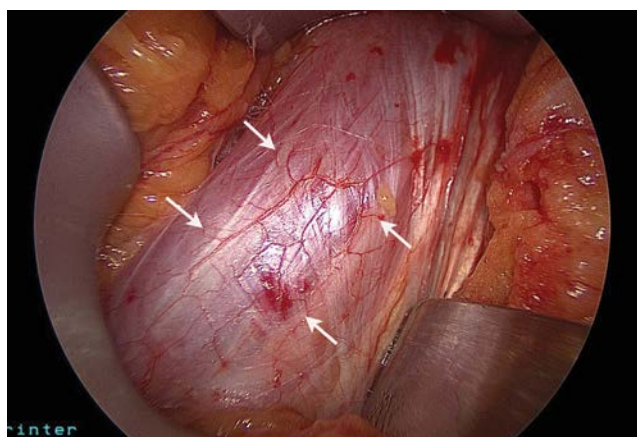


Figure 102.9 Attenuated external oblique aponeurosis (arrows) as seen in an open repair.

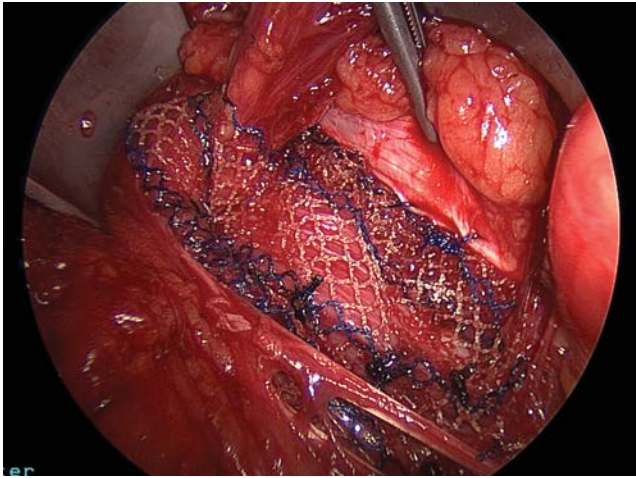


Figure 102.10 Open mesh repair of right inguinal floor.

rectus sheath medially and to the inguinal ligament laterally (**Figure 102.10**). The mesh is split and the two limbs are brought around the cord and sutured to the inguinal ligament above the internal ring in the Lichtenstein fashion so that the mesh will lie evenly in the floor and not because there is pathology at the internal ring. An effort is made to cover the mesh by suturing the internal oblique muscle over to the inguinal ligament with an absorbable suture so that the spermatic cord will not be in direct contact with the mesh. The ilioinguinal nerve is resected selectively in cases in which it appears partially entrapped in a slit in the external oblique or if its position is such that it may be in extensive contact with the mesh in order to prevent postoperative neuralgia.

SURGICAL OUTCOMES

The largest reported series of open primary repair was reported by Meyers in 2008.⁷ He operated on over 5,200 athletes from 1986 to 2008 with successful return to sport in approximately 95%. Muschawek¹⁶ described outcomes of the minimal repair technique in 128 athletes. Successful return to sport at 4 weeks was achieved in 83.7% of athletes, but long-term results have not been reported. Experience with open anterior mesh repairs has been described by several groups with return to sport in over 90%. Brown et al.¹⁹ reported outcomes in 98 professional or elite-level hockey players over an 18-year period. They used a polytetrafluoroethylene (PTFE) patch placed underneath the external oblique aponeurosis and resected the ilioinguinal nerve in all cases. Recurrent symptoms or injuries were observed in 3 athletes, and overall 97 of 98 successfully returned to sport. The author has performed repairs for sports hernia in over 200 athletes over the last 10-plus years, and an open tension-free mesh repair was utilized in 87% of cases.²⁰ Return to full athletic activity has been achieved in 92% of athletes at a mean follow-up interval of 11.4 months.

The reported experience with and outcomes for a laparoscopic approach to sports hernia repair are listed in **Table 102.1**.^{21,23,26–34} In the only comparison of laparoscopic and open approaches done to date, Ingoldby analyzed outcomes in 28 athletes.²³ Fourteen athletes had open repairs (3 primary sutured repairs and 11 Lichtenstein tension-free mesh), and 14 were done laparoscopically (TAPP). Both approaches reported successful return to sport in a high percentage of cases, but the laparoscopic approach was associated with a somewhat quicker return to activity at 4 weeks postsurgery (64.2% versus 92.9%). Two athletes in the laparoscopic group had neuralgia symptoms that resolved after 2 months. One case of recurrent symptoms was observed in each group.

Most reported laparoscopic series are relatively small and include under 50 patients and are from European centers. In the largest laparoscopic series reported to date, Evans²⁷ reported outcomes in 287 athletes who underwent laparoscopic mesh repair using the TAPP approach. Of note is that a bilateral repair was done in 161 cases (56%), of whom 31% were asymptomatic on the contralateral groin. The reasons for bilateral repair in the asymptomatic patients were unclear. Of 192 patients in whom data were available, 80% were playing sport by 3 weeks and 90% at 4 weeks. In long-term follow-up, there were 8 recurrences that required laparoscopic reoperation. Genitsaris and colleagues³⁰ operated on 131 patients who failed 2–8 months of conservative management. A bilateral TAPP repair was carried out in all cases because of the finding of a posterior wall defect on the contralateral side, even though 33 patients had only unilateral symptoms. All athletes returned to sport at 3 weeks after surgery, and there was only one failure (0.76%) during follow-up.

A combined laparoscopic (TEP) floor repair and adductor tenotomy was performed by Rossidis et al.³⁴ in a series of 54 athletes. The majority of athletes played American football, and an MRI showed a rectus stripping injury with associated adductor longus origin strain in 26%. The tenotomy was performed via a separate incision made over the upper adductor longus and 1 cm below the tendinous insertion on the pubis. A standardized rehabilitation protocol was followed by the athletes, and return to sport was achieved at a mean of 24 days.

An alternative laparoscopic approach has been employed by Lloyd²¹ who has postulated that tension in the ligament is a primary source of pain in this condition. In this procedure, a laparoscopic TAPP procedure is carried out, and the inguinal ligament is released medially near its insertion on the pubic tubercle. The area is then reinforced with a polypropylene mesh in a standard fashion. In the early experience with this technique, return to sport was successful in 92% of athletes treated with this technique at a mean of 28 days. Further studies are needed to confirm the results of this approach before it can be recommended.

The British Hernia Society held a consensus conference in 2014 that addressed several questions regarding nomenclature, diagnosis, imaging, and treatment of sports hernia.⁹ The consensus panel comprised surgeons who did only open, only laparoscopic, and one who did both. In regard to the question

of which operative approach should be used, there was no clear consensus on whether an open or laparoscopic approach should be used. However, the laparoscopic repair had a somewhat quicker return to activity and sport, although no controlled comparisons have been done. It was emphasized that an individual surgeon's expertise is often the primary variable in dictating the type of repair that is undertaken.

POSTOPERATIVE MANAGEMENT AND RETURN TO SPORT

An important component of the treatment and recovery from surgery for sports hernia is physical therapy and post-operative rehabilitation. The author has worked with a professional athletic trainer to develop a rehabilitation protocol that is used as the template for recovery in all athletes.²⁵ This approach consists of a stepwise program that comprises abdominal core strengthening as well as an emphasis on strength, flexibility, and balance of the thigh musculature and lower extremity. The first 5 days consist of relative rest and walking. A structured program then begins that consists of more extended walking progressing sequentially to light jogging, stationary biking, and core and lower body exercises. At 2 weeks, or as soon as it is comfortable, scar massage and mobilization may commence. The athlete is encouraged to begin low-level sports-specific activity (dribbling a soccer ball, skating, running, or catching a football) at 2–3 weeks and increase the speed and intensity from that point forward according to symptoms. With the minimal repair technique, Muschawek has reported an accelerated path for return to sport in athletes that allows resumption of training within 3–4 days and has resulted in a return to play as early as 3–4 weeks after the procedure.¹⁶ Regardless of the approach, a tension-free mesh repair should also allow early training and progression according to comfort level. In many cases, repairs are often done in the off-season, and a more conservative timetable for return to play is generally utilized. It is important to note that return to play may take longer in athletes who have significant adductor or other associated injuries.

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Laparoscopic robotics

OMAR YUSEF KUDSI, ANTHONY GONZALEZ, ZACHARY MCCABE, AND ERNESTO DOMINGUEZ

INTRODUCTION

The sketches of Leonardo da Vinci showed a humanoid robot design, which might be related to his famous anatomical study of the human body in the Vitruvian Man sketches. The ideas of da Vinci inspired many across centuries, even medical device companies, as the current surgical robot is named after him. Currently, the most commonly used surgical robot follows a master-slave relationship, with full control by the master surgeon at the console.

In the 1990s, laparoscopy revolutionized surgery and created a new division in general surgery called minimally invasive surgery (MIS) as a subspecialty. As a result, it challenged surgeons across the globe to acquire this new technology to benefit their patients. Almost a decade later, Intuitive was able to develop a U.S. Food and Drug Administration (FDA)-approved robotic system based on the foundation of early works funded by the U.S. Department of Defense on telerobotic surgery, as well as technologies from International Business Machines (IBM), the Massachusetts Institute of Technology (MIT), and Stanford Research Institute (SRI). Since then, robotic technology continues to evolve in the market while other companies prepare to enter this arena. As of the end of 2012, more than 2,500 da Vinci Surgical Systems were being used in over 2,000 hospitals worldwide. Intuitive has the lion's share of the market by holding the exclusive field-of-use license for more than 1,000 patents. Recently, Ethicon announced a new collaboration with Google to explore how the latest innovations in computer science and advanced imaging and sensors could be integrated into new robotic surgical systems.

LAPAROSCOPIC ROBOTICS IN GENERAL SURGERY

The evolution of robotic surgery as previously described was an initiative of the U.S. Department of Defense. The robot

was intended to assist severely wounded soldiers in the battlefield to prevent casualties. The first robotic platform was intended for open surgery; it had two large cameras, and it was not focused on MIS.

It was the visionary Fred Moll (Intuitive Surgical, Inc.) who formulated the hypothesis of the robot to solve the limitations seen in laparoscopic surgery, such as the lack of articulation of its instruments, inadequate precision, and nonintuitive motion due to the length of laparoscopic tools. Therefore, the new robotic platform intended for MIS was developed following three basic principles that still persist today: (1) a master/slave, software-driven system that provided intuitive control of a suite of seven degrees-of-freedom laparoscopic instruments; (2) a stereoscopic vision system displayed in an immersive format; and (3) a system architecture composed of redundant sensors to provide maximum safety in operation.

In March 1997, Intuitive Surgical tested the first prototype in humans and subsequently obtained FDA approval in July 2000.¹

THE STANDARD DA VINCI SYSTEM

The robotic system consists of the surgical console, a vision cart (tower), and the robot. The console consists of the binocular three-dimensional (3D) visualization system, a padded armrest, and the "masters." It also has pedals for camera control, resetting master controllers, and for the use of energy devices. The first robot was released with only three arms, one for the camera and two for the robotic instruments.

Limitations noticed on this platform were seen in procedures that required operations in more than one quadrant in the abdominal cavity, such as colorectal surgery. In the first generation (Standard), the arms could not self-adjust around the bed to allow the surgeon access to more than one quadrant of the abdominal cavity—it required repositioning of the surgical cart during various stages of the operation.

In December 2002, the Standard version with four arms was released. This allowed the surgeon to have an additional robotic arm to retract structures. This additional arm, like the three previous, could easily be repositioned by the surgeon at the console, which in turn, decreased surgical time.

Moving the robot was difficult and time consuming due to its size and weight. To address this issue, Intuitive released a Si that consisted of a motorized patient cart and efficient mounts for faster patient docking. With the fourth arm integrated, deployment was more rapid and less cumbersome.

The role of robotics was very limited in cases requiring multiquadrant surgery. Many times these complex surgical procedures (colorectal surgery) required hybrid procedures combined with standard laparoscopic surgery.²

DA VINCI SI

The da Vinci Si was approved by the FDA in February 2009. This model includes dual-console capability to support training and collaboration during surgery. The advantages provided by this device were longer instruments and the ability to reach two quadrants of the abdomen without the need to redock the robot ([Figure 103.1](#)). Furthermore, the development of EndoWrist robotic staplers, the bipolar wristed vessel, and the introduction of the Firefly technology (indocyanine green [ICG]) made this platform the most advanced in MIS. In December 2011, the single-site platform for the da Vinci Si obtained approval by the FDA to perform single-incision cholecystectomy. The single-site platform for the da Vinci Si was designed to offer the adequate triangulation required in MIS.

DA VINCI XI

As the robotic technology continues to evolve, the recently designed da Vinci Xi platform enables placement of the surgical cart at any position around the human body, enabling access to four anatomical quadrants. The endoscope can be

mounted on every robotic arm giving the surgeon more flexibility, its instruments can reach farther than the previous platforms, and the ports can be placed closer without affecting triangulation or conflicts. Currently, the single-site platform has not yet been released to the market and is in the FDA approval process. However, a new concept of single-site robotic surgery is simultaneously being developed by Intuitive, the da Vinci SP. This single-site platform designed to work on the Xi includes four wristed instruments (including the camera).

ADVANCED ROBOTIC TOOLS

Firefly (indocyanine green)

Fluorescence-guided surgery utilizing the ICG vital dye at a dose of 0.1–0.5 mg/kg (should not exceed 2 mg/kg) is currently used for fluorescent intraoperative cholangiography, bowel perfusion assessment, and lymph node mapping. It is broadly used in urology and gynecology ([Figure 103.2](#)).

Vessel sealer

The EndoWrist vessel sealer is an advanced bipolar instrument used to coagulate and divide vessels up to 7 mm in diameter. It is wristed and versatile to work within very limited spaces, such as in foregut surgery, bariatric surgery, and splenectomy or low anterior resection.

EndoWrist robotic stapler

The robotic stapler that is fully controlled from the console has Smart Clamp technology that provides feedback to the surgeon regarding the thickness of the tissue to be stapled compared to staple height in the robotic stapler load. If the sensors on the stapler detect that the tissue is too thick for the load applied, it will not fire.

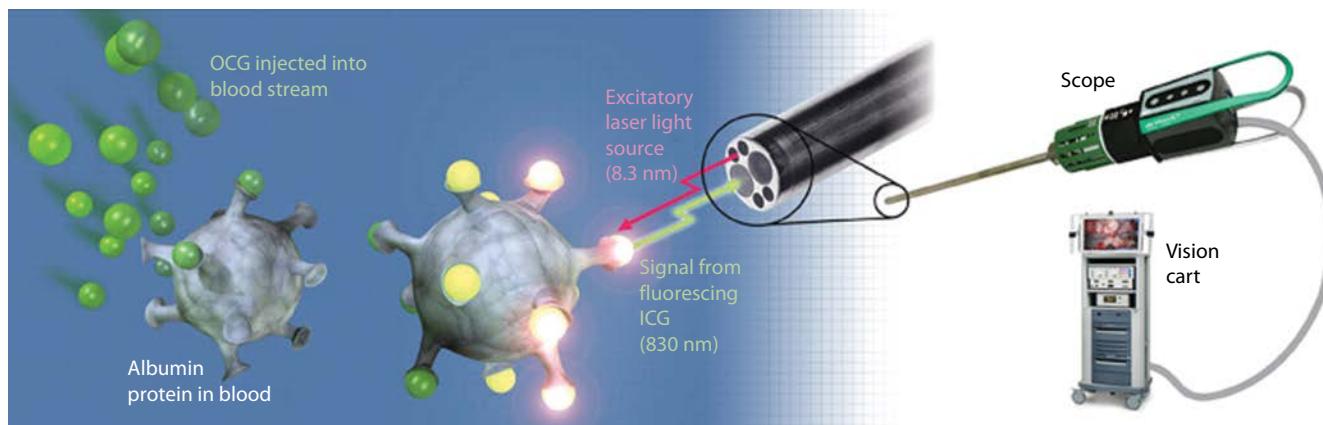


Figure 103.1 A dual console allows two surgeons to share control of the surgical robot simultaneously.



Figure 103.2 FireFly technology is capable of emitting laser light that is close to infrared light with the flexibility to switch using dedicated commands at the console between white light and near-infrared (NIR) light view in real time, thus enabling surgeons to perform fluorescence-guided surgery utilizing the indocyanine green (ICG) dye.

Advanced Robotic Ultrasound Technology from BK Medical provides a curved linear probe and guarantees a unique real-time 3D visualization of the target anatomy.

CLINICAL

Robotic surgery has progressively played an increasing role in every subspecialty in general surgery, including endocrine, such as thyroidectomy, colorectal, bariatric, and foregut, and solid organ, such as adrenalectomy, hepatobiliary, pancreatic, and hernia. Overall, the impression is that this technology is enabling surgeons to offer the minimally invasive approach to patients with challenging surgical scenarios that make conventional laparoscopic surgery cumbersome or impossible ([Figure 103.3](#)).

As robotics continues to expand across other specialties, more collaboration is noted among general surgeons,

urologists, and gynecologists when intraoperative consultations occur.³

LIMITATIONS IN LAPAROSCOPIC ROBOTICS IN GENERAL SURGERY

Despite the fact that robotic technology could enable surgeons to overcome the existing limitations in laparoscopic surgery and expand the MIS procedures offered to patients, it comes with some limitations. The major current limitations described in robotic surgery are related to increased costs, prolonged surgical times, and learning curves. Since robotic surgery has been continuously evolving, these limitations should be constantly reviewed.

COST

Robotic technology faces several challenges, including steep learning curves and extensive practice and training. Physician training is a major limiting step that comes at a significant price (time spent away from practice, time spent on simulation, time spent on cadaver, proctoring, learning curve, and finally team training to achieve efficiency). Perhaps the greatest challenge is the significant fixed cost with robotic surgery, with additional costs arising from maintenance contracts and disposable robotic instruments.

Rosemurgy et al. performed a study to compare the cost of care and reimbursement of robotic versus laparoscopic cholecystectomy. They found that robotic cholecystectomy took longer with higher charges (\$8,182.57 greater) than laparoscopic cholecystectomy ($p < 0.05$ for each). However, revenue, earnings before depreciation, interest, taxes, and net income were not impacted by approach. Hence, the costs were found to be similar among approaches. One of the authors (AMG) has had similar findings within his institution, demonstrating the costs of laparoscopic

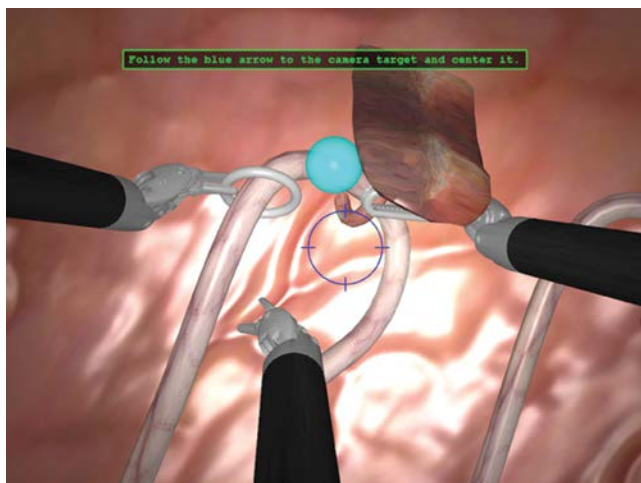


Figure 103.3 Robotic simulation exercise in order to achieve the necessary robotic skills.

cholecystectomy, single-incision laparoscopic surgery, and single-incision robotic surgery were not different.

It is from our perspective that to compare surgical times, efficiency, costs, and safety, new evidence-based conclusions should be performed only from studies that involve the Si and Xi platforms to avoid confounding bias that may be related to obsolete limited platforms.

Currently, Intuitive Surgical, Inc. has the monopoly on robotic surgery. It is perceived by the surgical community that as more robotic companies enter the market, competition will create a price reduction. Thus far, no high-level data are available analyzing the cost over time versus the cost of reduction of complications.

TECHNICAL

The surgical robot is still considered bulky and occupies a large space in the operating room. This also raises major concerns with moving the robot between operating rooms. The console is located separately from the patient's bedside, which could disrupt intraoperative team communications and delay team response to an emergency conversion. Therefore, it is recommended to perform simulation emergency conversion. Team training is recommended to reduce the time to set up such complex technology.

Lack of haptic feedback during robotic surgery is an obvious drawback despite the existing enhanced high-resolution 3D imaging. The loss of haptic feedback impacts judgment of force applied during surgery, such as tissue handling compliance, texture, or elasticity. However, a study performed by Mucksavage et al. compared grip forces among three different robotic platforms, specifically looking at the robotic instruments commonly used during urologic surgery, and among the Standard, the S, and the Si platforms. The grip force of the robotic instruments tends to be less than that observed in comparable open surgery instruments, suggesting the general safety of robotic instruments in handling delicate urologic tissues.

CLINICAL

Robotic skills require specialized training for the surgeon and the surgical team, and time away from practice. There is a steep learning curve for the surgeon and the robotic team to become proficient in the necessary skills and performance. In 2015, the majority of academic medical centers in the United States did not provide formal training in robotic surgery and lacked the funding for such fellowships on a national level (Figure 103.4). Overall, technology is advancing at a faster pace than surgical education; hence, there exists a large deficit in robotic training.

Obtaining robotic privileges is becoming more and more difficult, and hospitals lack standardized credentialing committees. Surgeons' access to robotic technology is one of the biggest clinical limiting factors; this is related to available



Figure 103.4 Robotic target anatomy through laser pointer that facilitates docking of robotic arms.

operative block time, available surgical team, and time of the day. The explosion of technology will continue to create more segmentation in the general surgery field and raise a concerning challenge for the average general surgeon to adopt this technology by attending advanced courses offered over 1 or 2 days, with minimal access to mentorship. Currently, closed groups through social media offer a promising platform to exchange knowledge in robotic technology with many groups hosting hundreds of active surgeon discussions and sharing experiences in robotic technology in general surgery and subspecialties (such as the global Robotic Surgery Collaboration group). Finally, it is crucial that leaders in the robotic general surgery field take the initiative of documenting their outcomes, publishing their results, and participating in clinical randomized controlled trials to provide convincing data of clinical effectiveness of robotics in general surgery and its cost benefit.⁴

TELESURGERY AND TELEMENTORING

Legal issues with health care are becoming very complex as surgical technology advances at a fast rate. Robotic surgery and emerging surgical technology have grown rapidly in the last decade. Perhaps the most significant challenge ahead of us is the application of laws to this cutting-edge technology that may not even have been contemplated when the laws were enacted. Telesurgery provides a challenge to the traditional physician-patient relationship model, and it poses a malpractice risk for telesurgery practitioners. Telesurgery requires sophisticated high-end technology, which is costly. Although world-class medical centers may be able to afford the high cost, smaller community hospitals may not. One of the potentials of telesurgery is the ability to offer telementoring and teleproctoring to these rural community hospitals, thereby allowing expert surgical consultation without the cost and burden of travel. In order to reach such potential, the issues of scalability and cost effectiveness must be addressed.

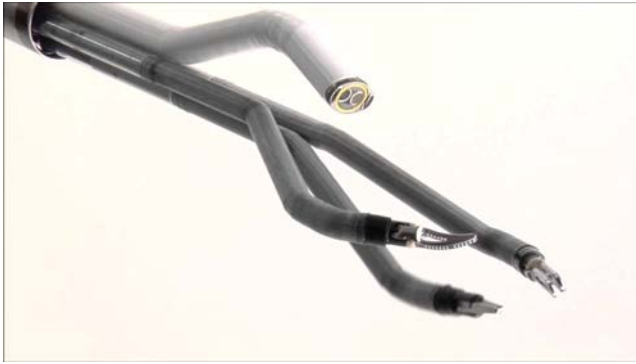


Figure 103.5 Future robotic single port technology from Intuitive.

CHALLENGES IN LAPAROSCOPIC ROBOTICS

There are technical challenges in the refinement of robotic surgical platforms, reduction of weight, cube, complexity and cost, and expansion of clinical applications. Other challenges include legal liability aspects of robotic surgery, telesurgery, telementoring, patient safety, Health Insurance Portability and Accountability Act (HIPAA) concerns, and reimbursement and insurance issues ([Figure 103.5](#)).

FUTURE OF LAPAROSCOPIC ROBOTICS

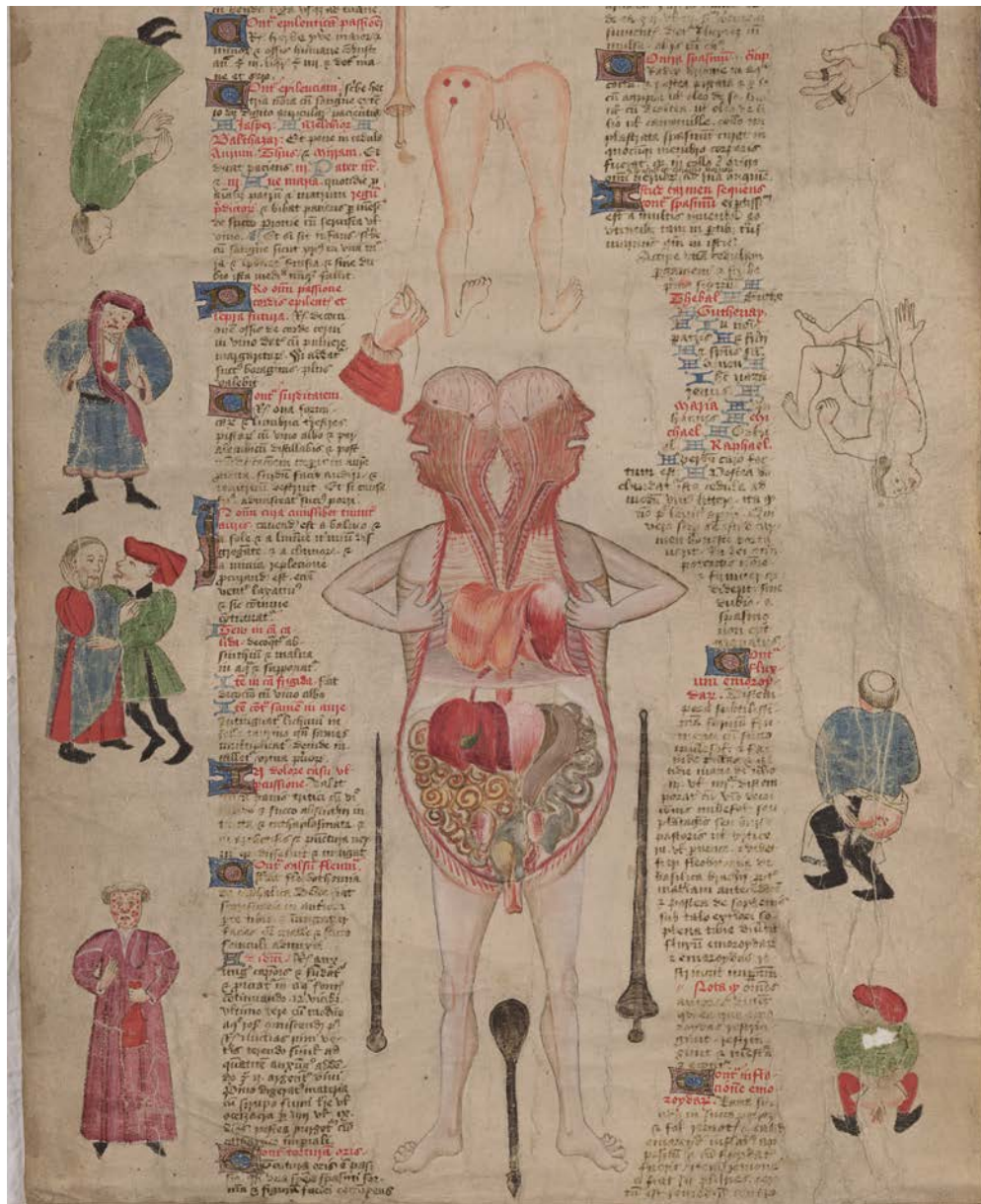
The existing surgical robot is a successful entrepreneurial story of visionary individuals and companies. It is the beginning of a long journey that will change the surgical landscape as new platforms continue to evolve for use by the different surgical specialties. This, in turn, will open the doors for new techniques and expand the horizon of robotics to hold the promise of becoming the central workstation of operating rooms.

I see this century as the turning point for robotic procedures, as technology has never advanced at such speed in our history. These robotic platforms will continue to evolve and eventually become the centerpiece of surgical care, which is likely to significantly change the practice of surgery.

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Thoracoscopy



Anatomical diagram from *De Arte Physicali et de Cirurgia* by John Arderne, 1412. National Library of Sweden, Stockholm.
(Artwork in the public domain; image courtesy National Library of Sweden, MS X 118.)

John Arderne (1307–92) has been called the “father of English surgery.” Born in Newark, England, he gained experience as a military surgeon in France, where gunpowder was used for the first time in battle. Around 1370 he moved to London, joined the Guild of Military Surgeons, and began to write about his career. Unlike most surgeons, who were less-trained barbers capable only of simple procedures, Arderne was respected by his physician colleagues who proudly described himself as “a surgeon among physicians.” His best-known work was the *Practica Chirurgiae* (*Practice of Surgery*) of 1370, which was used to teach surgery in medieval medical schools throughout Europe. This illustration comes from a copy of a manuscript entitled *De Arte Phisicali et de Cirurgia* written by Arderne on a scroll of parchment dating back to 1412.

The cadaver here, which is split into two from the hips up, reflects fifteenth-century surgeons’ lack of anatomical knowledge. The hand above the cadaver holding the string refers to one of the procedures Arderne describes—treatment for anal fistulae—a common ailment for knights on horseback that prior to this time had no effective remedy. After tying the string to a probe, he passed it from the opening in the skin through the tract to the rectum. He then cut open the entire tract, allowing it to heal from the inside out. He designed new tools for the process and treated the wound with ointments and oils rather than with the usual, more corrosive

materials. Arderne claimed that his technique, which shared basic principles with today’s treatments, had a survival rate of 50 percent—extremely high for that time.

While the text of the manuscript is meant primarily to advertise and explain the technique, it also contains comments and illustrations to establish Arderne’s status and that of the surgical profession. He warned his readers—other master surgeons—that they should not share his anal fistula technique with barbers, or they would put patients in danger with their attempts to perform it. It also includes Arderne’s opinions on how surgeons should behave with patients: For example, they should dress “like a clerk and not like a minstrel”; that when speaking “be the words short, and, as much as he may, fair and reasonable and without swearing”; and that they should be ready to calm patients with comforting and moral stories if they were in pain or became upset.

Sara Oberg Stradal, “John of Arderne: The Father of English Surgery,” *University of Glasgow Library*, published September 25, 2012, <https://universityofglasgowlibrary.wordpress.com/2012/09/25/john-of-arderne-the-father-of-english-surgery/>.

Text by Mariann Smith, courtesy Center for Medical Humanities, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo.

Thoracoscopic surgery of the mediastinum and esophagus

NASSRENE Y. ELMADHUN AND MICHAEL KENT

INTRODUCTION

Video-assisted thoracoscopic surgery (VATS) and its uses have been evolving over the last several decades. Whereas it used to be reserved for the surgical approach to pleural and pulmonary diseases, its uses have expanded to address diseases of the mediastinum. The role of thoracoscopic surgery of the mediastinum is no longer confined to diagnostic procedures for mediastinal disease, but also as a viable alternative to open surgery. The focus of this chapter is on the application of VATS for mediastinal disease.

The anatomy of the mediastinum is traditionally divided into three compartments: anterior, middle, and posterior. Bound by the sternum anteriorly and the pericardium posteriorly, the anterior compartment extends from the diaphragm to the thoracic inlet and includes structures such as thymus, innominate vein, the anterior surface of the arch vessels, internal thoracic vessels, and intrathoracic thyroid and parathyroid glands. The middle compartment is bound by the pericardium anteriorly and the vertebral bodies posteriorly, and contains structures including the heart, great vessels, trachea, hilar bronchi, superior vena cava, phrenic nerve, paratracheal and subcarinal lymph nodes, and esophagus. Finally, the posterior compartment extends anteriorly from the surface of the vertebral bodies to the paravertebral sulci and includes structures such as the sympathetic chain, intercostal nerves and vessels, paraesophageal lymph nodes, distal esophagus, descending thoracic aorta, and the proximal thoracic duct ([Figure 104.1](#)). The anatomic distinctions are important when developing a differential diagnosis in patients with a defined mediastinal mass ([Table 104.1](#)).

THORACOSCOPIC THYMECTOMY

Patients with thymic cysts, thymic hyperplasia, or thymoma <4 cm without evidence of local invasion can be considered for VATS thymectomy. In addition to the VATS approach, thymectomy can be approached robotically. The surgical approach for VATS thymectomy has been described both from the left and from the right. A left-sided approach minimizes injury to the superior vena cava, while improving visualization of the pericardiophrenic angle and aortopulmonary window. A right-sided approach facilitates visualization of the superior vena cava-innominate vein junction and allows for improved instrument maneuverability in the wider right pleural cavity ([Figure 104.2](#)). In this chapter, we describe a right-sided approach to thymectomy.

Operative steps

The patient is intubated with a double-lumen tube and placed on the operating table in left lateral decubitus position. A 10 mm camera port is placed in front of the tip of the scapula along the posterior axillary line. Two additional 5 mm instrument ports are placed in the third intercostal space along the midaxillary line and sixth intercostal space in the anterior axillary line. The pleura anterior to the phrenic nerve is grasped, and the mediastinal pleura is entered parallel and anterior to the phrenic nerve on the right toward the superior vena cava. The right inferior pole of the thymus is then bluntly dissected from the pericardium. The mediastinal pleura is identified over the left lung, and the pleura is incised. The left thymic pole is identified and dissected off the diaphragm and the pericardium. The mediastinal pleura is incised anterior and parallel to the left phrenic nerve

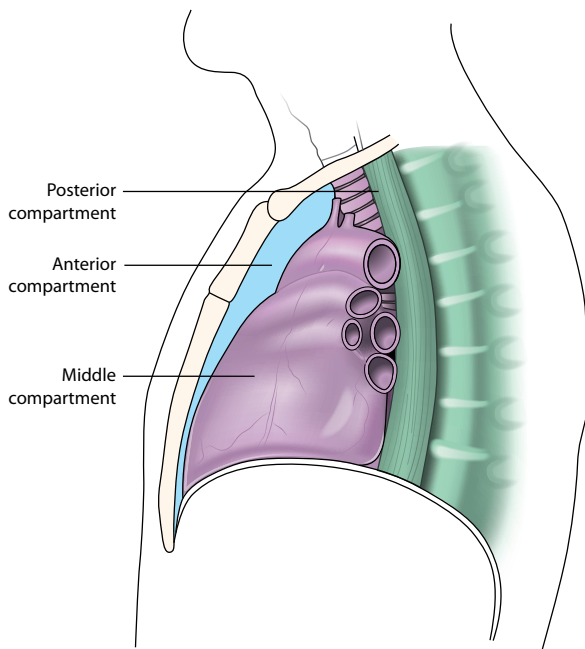


Figure 104.1 Compartments of the mediastinum. (From Sugarbaker DJ et al. *Adult Chest Surg*, 2nd ed. www.accesssurgery.com. Copyright © McGraw-Hill Education. All rights reserved.)

cranially to the innominate vein. The thymic draining tributaries (usually two or three) draining into the left innominate vein are identified, clipped, and divided. The cervical poles are dissected down from the neck. The right internal mammary vein can be divided to facilitate the exposure. Of note,

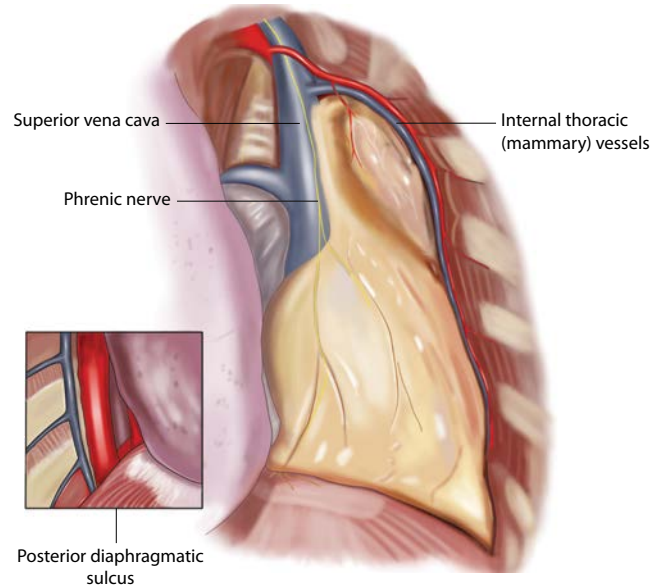


Figure 104.2 Mediastinal landmarks visible from right thoracoscopic approach. (From Sugarbaker DJ et al. *Adult Chest Surg*, 2nd ed. www.accesssurgery.com. Copyright © McGraw-Hill Education. All rights reserved.)

the surgeon should be aware that the left superior horn can occasionally pass behind the left brachiocephalic vein. The specimen is removed through a retrieval bag. The thymic bed is inspected for hemostasis, and a Blake drain is left in place postoperatively to drain the pleura and mediastinum.

Table 104.1 Differential diagnosis for mediastinal mass based on anatomic compartment

<i>Anterior compartment</i>	<i>Middle compartment</i>	<i>Posterior compartment</i>
Thymus	Airway	Neurogenic
• Thymoma	• Bronchogenic cyst	• Neurofibroma
• Thymic cyst	• Tracheal cyst	• Neuroblastoma
• Thymic hyperplasia	• Tracheal tumor	• Pheochromocytoma
• Thymic cancer	Pericardial cyst	Meningocele
Lymphoma	Lymphadenopathy	Thoracic duct cyst
Germ cell tumor	• Lymphoma	Connective tissue
Thyroid	• Metastasis	• Angiomyolipoma
Parathyroid	Enteric cyst	Esophagus
Vascular	Vascular malformation	• Enteric cyst
• Hemangioma		• Esophageal tumor
Connective tissue		• Esophageal diverticuli
• Lipoma		Vascular
• Liposarcoma		• Aneurysm
• Fibroma		
• Fibrosarcoma		
Morgagni hernia		

VIDEO-ASSISTED THORACIC SURGERY RESECTION OF NEUROGENIC TUMORS

Neurogenic tumors often arise in the paravertebral sulcus in the peripheral nerve or sympathetic ganglia. The most common neurogenic tumors in adults are schwannomas and neurofibromas, and they are usually slow growing and benign. Preoperative imaging is necessary to rule out intraspinal extension. Dumbbell-shaped tumors with a portion of the tumor within the spinal canal or neural foramen necessitate a combined neurosurgical laminectomy and lateral thoracic approach for resection.

Operative steps

The patient is intubated with a double-lumen tube and placed in a lateral decubitus position. The ipsilateral lung is isolated. The camera port is placed posteriorly, the operating ports are placed anteriorly, and an additional port is placed superior anteriorly to retract the lung. Once the tumor is identified, the pleura and investing fascia over the tumor is incised and separated from the surface of the tumor. The tumor is freed from its attachments to the chest wall to expose the stalk at the base of the tumor where it is attached to the neural origin.

Vessels feeding the tumor are carefully clipped and divided. The stalk is clipped and divided. The specimen is placed in a retrieval bag and removed. The surgical site is carefully inspected for evidence of a cerebrospinal fluid leak. A chest tube is placed at the conclusion of the procedure.

VIDEO-ASSISTED THORACIC SURGERY SYMPATHECTOMY

The most common indication for sympathectomy is hyperhidrosis involving the palmar, plantar, and axillary regions. Patients who have failed nonoperative management should be counseled that there is a high incidence of compensatory sweating postoperatively. Thus, if the patient is experiencing sweating of the trunk, groin, buttocks, or thighs, the risk of compensatory sweating postoperatively is increased. Other indications for thoracic sympathectomy include reflex sympathetic dystrophy, Raynaud's disease, and upper extremity ischemia.

Operative steps

The patient is intubated with a double-lumen endotracheal tube and placed on the operating room table in a supine semi-Fowler's position with the arms abducted at right angles, and a roll behind the shoulders. The ipsilateral lung is isolated. Two 5 mm ports are placed in the third and fifth intercostal spaces along the anterior axillary line. Brief insufflation to 15 mm Hg with carbon dioxide helps to rapidly deflate the lungs. A telescope and camera are placed in the inferior port. The second rib is identified, which is the first rib that is visible at the apex of the chest. The pleura over the sympathetic chains lateral to the vertebral bodies over the ribs is incised using hook cautery. The ganglia are identified, and hook cautery is used to divide the lateral and medial aspects of the ganglia. The dissection is carried out 5 cm lateral to the chain to ensure that any aberrant nerve bundle of Kuntz is identified and also severed. The transected ends of the sympathetic chain are separated to prevent regrowth of the nerve and recurrence of symptoms. For palmar hyperhidrosis, levels T2 and T3 are divided. For thoracic reflex sympathetic dystrophy, T1-T3 is divided. The procedure is repeated on the contralateral side. At the conclusion of the procedure, the lungs are inflated with positive pressure ventilation with a drainage tube in one of the incisions to facilitate evacuation of any residual pneumothorax. The incisions are closed, the tube is removed from the last incision, and the final subcuticular suture is placed. A postoperative chest radiograph is obtained immediately to ensure complete lung expansion.

PARASTERNAL MEDIASTINOTOMY

Parasternal mediastinotomy is a technique used to biopsy anterior mediastinal lymph nodes in the mediastinal node

station 5 (aortopulmonary window) or 6 (preaortic). Patients without mediastinal lymph node involvement may proceed directly to surgical resection. However, patients with positive lymph nodes may require preoperative chemoradiation. Therefore, an accurate assessment of the mediastinal lymph nodes plays an important role for determining the appropriate therapy in lung cancer patients. In order to sample station 5 and 6 lymph nodes, a parasternal mediastinotomy can be approached either by VATS, open, or with a mediastinoscope. Here, we describe a parasternal mediastinoscopy to sample station 5 and 6 lymph nodes.

Operative steps

The patient is positioned in supine position on the operating table with the arms at the patient's side. The patient is intubated with a single-lumen endotracheal tube. The laterality is determined based on the position of the lesion of interest on preoperative imaging. A 3–4 cm incision is made over the second intercostal space (**Figure 104.3**). The dissection is carried down through the pectoralis muscle. The costal cartilage can be resected by disarticulating it from the rib and the sternum; however, this is not always necessary if the exposure is adequate through the intercostal space. The parietal pleura is swept laterally, and the internal thoracic vessels are swept medially to gain access to the mediastinum. For left-sided incisions, insertion of the mediastinoscope through the parasternal mediastinotomy will enter to the level of the aortopulmonary window for stations 5 and 6 lymph node biopsy. On the right, insertion

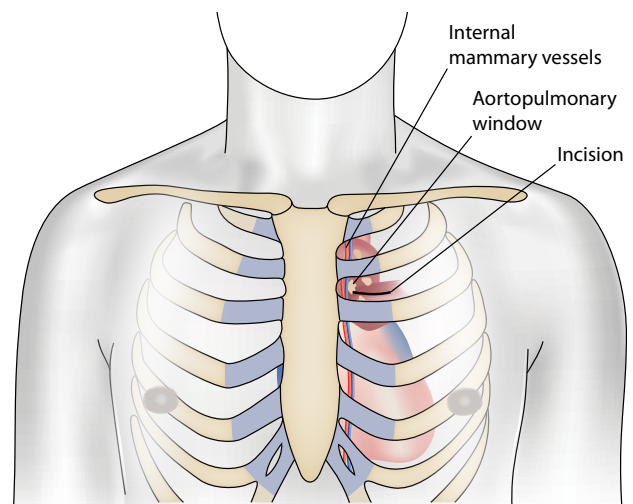


Figure 104.3 Landmarks for approach to parasternal mediastinotomy. (From Sugarbaker DJ et al. *Adult Chest Surg*, 2nd ed. www.accesssurgery.com. Copyright © McGraw-Hill Education. All rights reserved.)

of the mediastinoscope will enter lateral to the superior vena cava. The tissues are bluntly dissected and biopsied. At the conclusion of the procedure, the pectoralis muscle layer is reapproximated. Prior to closure, the lungs are hyperinflated with positive pressure ventilation to facilitate pneumothorax evacuation.

THORACOSCOPIC SURGERY OF THE ESOPHAGUS

Esophageal myotomy

Indications for a transthoracic approach to esophageal myotomy as opposed to a laparoscopic approach include prohibitive intra-abdominal adhesions, ipsilateral lung pathology requiring surgery, planned resection of an esophageal pulsion diverticula, and need for a proximal myotomy that would not be accessible through a transabdominal approach.

ANESTHETIC CONSIDERATIONS/PATIENT POSITIONING

Preoperatively, patients should be maintained on a liquid diet for several days. Patients are placed in mild reverse Trendelenburg position, and rapid sequence intubation is performed to minimize the risk of aspiration. A double-lumen endotracheal tube is used to isolate the left lung. Endoscopy may be necessary to evacuate esophageal contents. A nasogastric tube is placed, and the patient is positioned in right lateral decubitus position.

OPERATIVE STEPS

The camera port is placed in the midanterior axillary line at the sixth–eighth interspace. One port is placed anterior and superior to the camera port to retract the lung, and two additional working ports are placed in the posterior axillary line inferiorly. An additional port can be placed at the costophrenic sulcus to allow for inferior displacement of the diaphragm to expose the hiatus. The inferior pulmonary ligament is divided, which allows for exposure of the esophagus. The mediastinal pleura overlying the esophagus is incised, and the distal esophagus is circumferentially mobilized, taking care not to injure the vagus nerves. An encircling Penrose drain or tape is placed around the esophagus. A longitudinal myotomy is started approximately 5–7 cm above the diaphragmatic hiatus at the level of the inferior pulmonary vein, and continues down through the phrenoesophageal ligament and onto the stomach for 1 cm. The longitudinal muscle layer is divided, and the incision is deepened until the circular muscle fibers are identified. The circular muscle fibers are divided either sharply with Metzenbaum scissors or with low-power hook electrocautery. The mucosal layer remains intact and characteristically protrudes through the myotomy. As the myotomy is carried distally, care is taken not to injure the mucosa, which is thinner at the esophagogastric junction, and may be more difficult to separate from the muscularis layer. The esophagogastric junction is often identified by the crossing branch of the left gastric vein at the phrenoesophageal ligament. The myotomy is

extended for 1 cm onto the stomach to divide the sling fibers of the stomach. The cut edges of the muscle are grasped and bluntly dissected back 180° to widely free the mucosa from the muscle layer to prevent rehealing of the cut muscle. An endoscope or a midsized bougie can be used to facilitate this dissection. A leak test is performed by filling the chest with warm saline and gently distending the esophagus with air to detect mucosal perforation. If the mucosa is perforated, the defect can be closed primarily with simple interrupted absorbable sutures. The repaired defect is then covered with a partial fundoplication or intercostal muscle flap. A chest tube is placed at the conclusion of the procedure.

RESECTION OF GASTROINTESTINAL STROMAL TUMOR/LEIOMYOMA OF THE ESOPHAGUS

Leiomyomas account for approximately two-thirds of all esophageal submucosal tumors, the remaining one-third include gastrointestinal stromal tumor (GIST), leiomyosarcoma, lipoma, fibroma, neurofibroma, schwannoma, granular cell tumor, glomus tumor, and carcinoid tumor. Tumors that arise from the muscularis propria include leiomyoma, GIST, and leiomyosarcoma. Indications for resection of a submucosal lesion include unremitting symptoms, increasing size, and need for a tissue diagnosis. Generally, enucleation is the preferred surgical intervention by thoracotomy, VATS, or endoscopic resection. Traditionally, upper and midesophageal lesions are approached from the right chest, while distal third esophageal lesions are approached from the left. However, with advanced minimally invasive techniques, the distal third of the esophagus can be approached via a right VATS technique.

Operative steps

The patient is intubated with a double-lumen endotracheal tube. Upper endoscopy is performed to confirm the location of the tumor. The patient is placed in left lateral decubitus position. The surgeon stands at the patient's back while the assistant stands at the front. A camera port is placed in the eighth intercostal space in the midaxillary line. A 5 mm port is placed in the anterior axillary line at the fourth intercostal space to retract the lung. A 5 mm port is placed in the eighth or ninth intercostal space posterior to the posterior axillary line for the energy device. An additional 5 mm port is placed posterior to the tip of the scapula for retraction. For distal esophagus tumors, a suture is placed through the central tendon of the diaphragm and pulled out through the chest wall to retract the diaphragm inferiorly. The inferior pulmonary ligament is divided. Endoscopy or 54-French bougie can be used at this time to help identify the lesion. The pleura over the esophagus is divided, and the esophagus is mobilized circumferentially to expose the tumor. A Penrose drain is placed around the esophagus if needed to visualize the

tumor. A longitudinal myotomy is made over the tumor. It is important to identify and preserve the vagal trunks. A plane is developed between the mass, muscularis, and sub-mucosal layers. This dissection can be difficult if there is inflammation or mucosal injury from preoperative endoscopic biopsy. The tumor is then enucleated. If necessary, a retraction suture can be placed in the tumor to avoid grasping the tumor during the dissection. The specimen is placed in a retrieval bag and removed from the chest. The esophagus is then carefully inspected to identify any

mucosal injury. A leak test is performed by insufflating air into the esophagus while it is submerged underwater. If a mucosal injury is identified, it is repaired primarily. The longitudinal myotomy is repaired using interrupted sutures. The ports are closed, and a chest tube is left in place at the conclusion of the case. If there is concern for possible postoperative leak, a drain can be placed along the esophagus and kept in place until the patient is tolerating a regular diet.

Video-assisted thoracic surgery lobectomy

ALESSANDRO BRUNELLI AND TIM BATCHELOR

INTRODUCTION

Thoracoscopy was first described over 100 years ago in the management of pleural effusions, mainly due to tuberculosis.¹ As management strategies for tuberculosis changed with the advent of effective antimycobacterial agents, the use of thoracoscopy fell away. The introduction of fiberoptic technology in the 1970s and 1980s led to a renewed interest in minimally invasive thoracic surgical techniques, or video-assisted thoracic surgery (VATS).

Lobectomy with mediastinal lymph node dissection remains the standard for the surgical treatment of early-stage lung cancer. Traditionally this is achieved via a thoracotomy, but in 1991 the first VATS lobectomy was performed.² Over the following decade, a number of surgeons refined the techniques required to safely remove a pulmonary lobe. The uptake of the technique was limited by a number of factors including concerns about oncological outcomes, the perceived difficulty of VATS lobectomy, and the technology available. From the evidence now available, VATS lobectomy does not appear to be an inferior oncological operation for the treatment of early-stage lung cancer.³ Furthermore, major improvements in imaging and stapling technologies have facilitated a significant increase in the uptake of VATS lobectomy worldwide.

Initially, two competing approaches to VATS lobectomy were described. Walker advocated a posterior approach⁴ that simulated the view seen during a posterolateral thoracotomy. McKenna popularized an anterior approach^{5,6} that was more of a departure from conventional thoracic surgery. With time, the anterior approach became the dominant method. Variations now include the four-port technique initially described by McKenna, a three-port technique popularized by the Copenhagen group,⁷ a two-port approach, or most recently, a uniportal technique.⁸ One technique does not appear to be superior to another.⁹

Observational studies of VATS lobectomy for lung cancer suggest better outcomes than an open thoracotomy:

- Less pain and better quality of life¹⁰
- Fewer complications^{11–16}
- Shorter hospital length of stay^{7,13–15}
- More likely to complete adjuvant chemotherapy¹⁸
- Improved long-term survival^{3,17,19}

There is considerable selection and publication bias in the literature, and many of the retrospective studies have been published by high-performing surgeons in high-performing centers. This has led some to ask whether the perceived benefits of VATS lobectomy are due to the skill of the surgeon rather than the surgical approach.²⁰ While some prospective studies have not shown any difference in long-term pain or quality of life,²¹ the publication of the first large randomized controlled trial would appear to confirm the superiority of a VATS approach.²²

Some international guidelines now recommend VATS lobectomy as the preferred approach in early-stage lung cancer.²³ VATS has been standardized²⁴ and must include the following:

- No rib spreading
- A utility incision of 4–8 cm in length
- An additional one to three ports
- Video guidance during dissection
- Individual dissection and transection of the hilar structures
- Standard lymph node sampling or dissection

INDICATIONS

According to a recent consensus statement, VATS lobectomy is indicated for tumors less than 7 cm in size and for N0/N1 disease. It is contraindicated if there is chest wall

involvement, and relatively contraindicated if the tumor invades hilar structures.²⁴ However, in experienced centers, previous pleural surgery, the presence of bulky lymph nodes, endobronchial pathology, pericardial invasion, diaphragmatic invasion, chest wall invasion, or neoadjuvant therapy have become relative rather than absolute contraindications.

Although patient selection for surgery follows accepted international guidelines,²⁵ current functional algorithms are based on patients operated on through an open approach. The reduction in morbidity observed following a VATS lobectomy¹¹⁻¹⁶ may be explained by the lesser impact of VATS on chest wall mechanics in addition to an obtunded systemic inflammatory response.²⁶ This effect is even more evident in patients with compromised pulmonary function.²⁷⁻³⁰ As the evidence base expands, it is possible that the current functional operability criteria will be revised to include higher-risk patients.

SURGICAL TECHNIQUE: GENERAL PRINCIPLES

Positioning and anesthesia

The patient is placed in a lateral decubitus position in a “praying” position with the operated side facing upward. The operated lung is isolated using a contralateral double-lumen endotracheal tube and one-lung ventilation, although a bronchial blocker can be used. More recently, nonintubated techniques with spontaneous ventilation have been reported to achieve good lung isolation, but their safety remains to be tested.³¹

For a standard operating room setup, a monitor is placed on each side of the table, one in front of the surgeons and one in front of the scrub nurse (**Figure 105.1**). A 30° video-thoracoscope is used as the 30° scope allows a superior and more flexible view within the chest cavity.

Port placement

The most widely used approach is the anterior approach in which the hilar structures are visualized and dissected from anterior to posterior. Initially, a 4–5 cm anterior utility incision is made just anterior to the latissimus dorsi muscle in the fourth or fifth intercostal space. The use of a soft plastic wound protector facilitates surgical exposure, allows the use of suction, minimizes tissue and intercostal nerve trauma, and prevents tumor seeding.

Initial inspection is important in identifying unexpected pathology, adhesions, and the level of the diaphragm. At this stage an additional one or two ports are created (**Figure 105.2**). In the two-port technique, a second 1.5 cm port is positioned inferiorly and posteriorly at the level of the seventh intercostal space just anterior to a line drawn vertically down from the scapula tip. The camera is usually placed in the utility incision for the upper lobes and middle

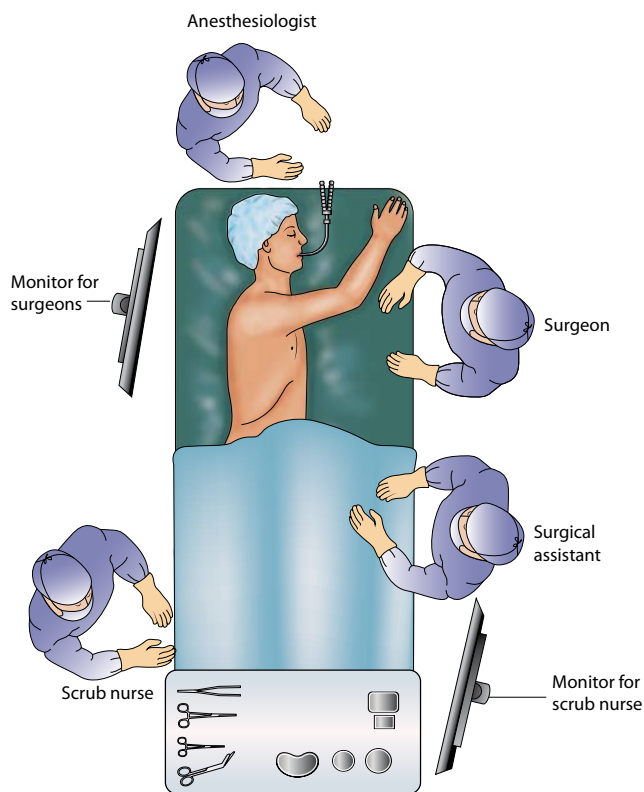


Figure 105.1 Operating room setup. The patient is placed in a lateral decubitus position with the surgeon and the surgical assistant standing facing the patient's abdomen. The scrub nurse faces the patient's back.

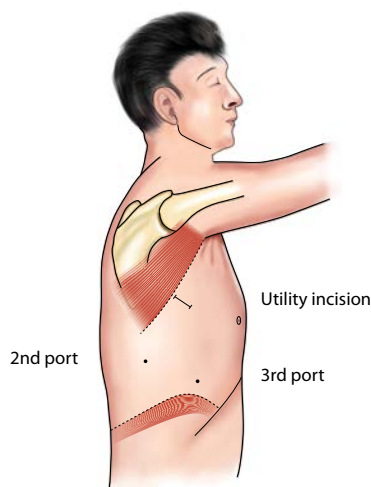


Figure 105.2 Port placement for VATS lobectomy. A utility incision is formed just anterior to latissimus dorsi in the fourth or fifth intercostal space. A second port is placed in the seventh intercostal space, just anterior to a line drawn inferiorly from the scapula tip. A third port may be placed anterior to this in the same intercostal space and in line with the utility incision.

lobe, whereas for the lower lobes it is usually placed in this second port.

In the three-port technique,⁷ a third port (which will become the camera port for the duration of the operation) is created in the same intercostal space as the second port, but more anteriorly and in line with the utility incision. This third port is positioned at the level of the dome of the diaphragm, anterior to the hilum, and will allow the camera to look along the length of the oblique fissure.

Hilar dissection

The inferior pulmonary ligament is divided first to expose the inferior pulmonary vein using a monopolar diathermy hook or an energy device. Dividing the pleural reflection and any covering mediastinal fat posterior to the phrenic nerve exposes the anterior hilar structures. In this way, the pulmonary veins are identified in addition to the origin of the pulmonary artery (Figure 105.3).

The lobar hilar elements are visualized, dissected free, and divided sequentially, from anterior to posterior. For each anatomical lobectomy, the pulmonary vein draining the lobe is usually the first structure to be divided, exposing the structure behind. For example, in a right upper lobectomy the next structure to be divided is the pulmonary artery truncus branch, followed by the posterior ascending arterial branch, followed by the right upper lobe bronchus.

The principles of dividing each tubular hilar structure (vein, artery, or bronchus) are the same. Each is dissected free from the surrounding tissues on either side to create an “entrance” and an “exit.” This allows an instrument to be passed safely behind (Figure 105.4). A silicone loop can be positioned around the structure to facilitate the placement of a stapling device. The structure is finally stapled and divided.

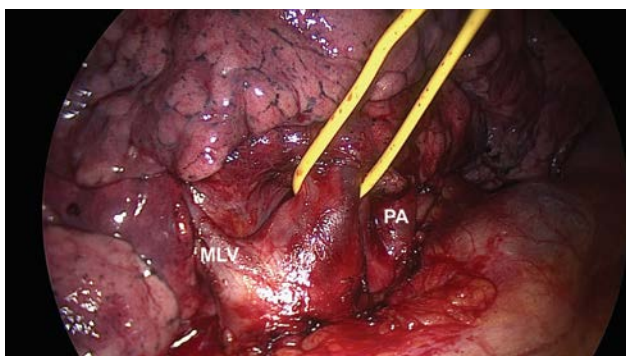


Figure 105.3 View of the right hilum during an anterior approach VATS upper lobectomy. The vein draining the upper lobe is encircled with a vessel loop and the pulmonary artery (PA) can be seen immediately behind it. The middle lobe vein (MLV) joins the upper lobe vein to form the superior pulmonary vein.

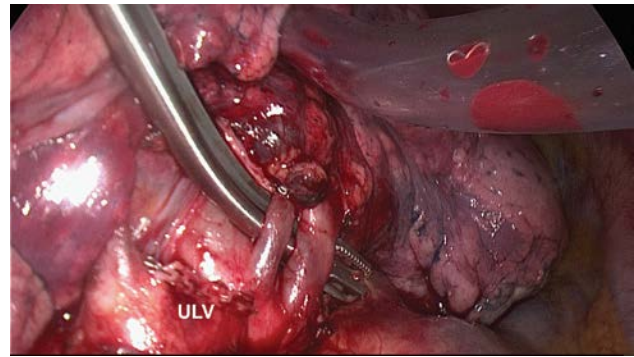


Figure 105.4 Dissection of the pulmonary artery branches to the right upper lobe. The upper lobe vein (ULV) has been stapled and divided, revealing the underlying pulmonary artery and its initial branches. A dissector has been used to free the arterial branches, ready for division.

Division of the fissures

The anterior approach has the advantage of being a “fissureless” technique in which the incomplete fissure is divided by stapling devices without breaching the visceral pleura. The fissure is often divided as the last step in a lobectomy after division of all the hilar structures (“fissure-last” technique). This approach minimizes visceral pleural and parenchymal injury and prevents alveolar air leaks. The lobe is then placed in a bag and retrieved through the utility incision.

After a mediastinal lymphadenectomy, a washout and underwater test is performed to check for air leaks. A regional anesthesia catheter (usually a paravertebral or intercostal catheter) may be placed, and additional intercostal blocks can complement this. At the conclusion of the operation, a single 24–28 Fr chest tube is placed through the inferior port and directed toward the apex of the chest.

SURGICAL TECHNIQUE: SPECIFIC LOBES

Right upper lobectomy

The lung is reflected posteriorly, and the mediastinal pleura and fat is divided to identify the bifurcation of the upper and middle lobe veins. Once the upper lobe vein has been clearly defined, it is dissected free and mobilized. A roticulated endomechanical stapler is introduced through the inferior port, with the anvil positioned behind the upper lobe pulmonary vein, which is then divided. This maneuver reveals the underlying pulmonary artery. In a similar manner, the pulmonary arteries to the upper lobe are mobilized and divided, beginning with the truncus anterior branch. Division of the posterior ascending segmental arterial branch occasionally requires the horizontal fissure to be completed first to allow better access. This is achieved by placing a stapler through the utility incision with the jaws

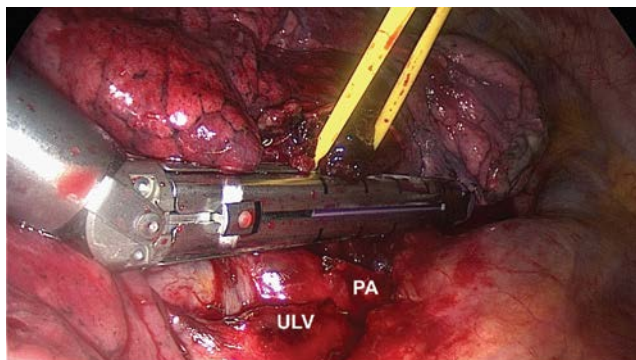


Figure 105.5 Division of the right upper lobe bronchus. The pulmonary arterial branches (PA) and upper lobe vein (ULV) have been divided. The last remaining hilar structure is the upper lobe bronchus. It has been encircled by a vessel loop and a stapling device has been placed, ready for division.

on either side of the horizontal fissure and the anvil resting on top of the pulmonary artery.

Division of the pulmonary artery branches reveals the right main bronchus, upper lobe bronchus, and origin of the bronchus intermedius. The upper lobe bronchus is dissected free. This may involve the mobilization of lymph nodes from its anterior and superior aspect. An instrument can be safely passed behind the bronchus, as there are no vascular structures situated posteriorly. The bronchus is then divided with a stapler and should be the last hilar structure to be transected (**Figure 105.5**). The horizontal and posterior oblique fissures are completed and the lobe removed.

Right middle lobectomy

The lung is reflected posteriorly. The mediastinal pleura and fat is divided, and blunt dissection is performed to identify the bifurcation of the upper and middle lobe veins as well as the inferior pulmonary vein. Once the middle lobe vein has been clearly defined, it is dissected free and mobilized. A stapler is introduced through the inferior port and the vein is divided, revealing the underlying right middle lobe bronchus.

The middle lobe bronchus is dissected free to allow visualization of its junction with the lower lobe bronchus. Care should be taken with the interlobar pulmonary artery, which sits immediately posteriorly. The bronchus is stapled and divided. An incomplete anterior oblique fissure can be completed at this stage.

Dividing the bronchus reveals the interlobar pulmonary artery. Its middle lobe branches are exposed and divided with a stapler. The horizontal fissure is finally completed and the lobe removed.

Left upper lobectomy

The lung is reflected posteriorly and the pulmonary veins identified. Caution should be applied when interpreting

the anatomy, as a common venous trunk is a well-known variation. The superior pulmonary vein is dissected free from the pulmonary artery trunk superiorly, encircled with an instrument introduced through the inferior port, and divided using a stapler. This maneuver exposes the bronchus. To facilitate dissection of the bronchus and prevent injury to the pulmonary artery branches, dissection of any lymph nodes between the superior aspect of the bronchus and the anteroapical segmental pulmonary artery branches is performed. The anteroapical branches of the arterial trunk can now be individually exposed and divided using a stapler introduced through the utility incision or inferior port.

Bronchial dissection can now be more easily accomplished by introducing an instrument through the inferior port. Subsequently, a stapler is introduced through the same port and the bronchus divided. However, care must be taken to define the secondary carina between the upper and lower lobe bronchi to prevent the entire left main bronchus from being erroneously encircled and divided, another well-recognized complication of left upper lobectomy.

Dividing the bronchus exposes the interlobar pulmonary artery in the fissure. Any remaining arterial branches (apical, posterior, and lingula) are dissected free and divided using a stapler passed through the inferior port. The fissure is finally divided with a stapler introduced through the inferior port and the lobe removed.

Lower lobectomies

The lung is retracted cranially, and the inferior pulmonary ligament is divided. The inferior pulmonary vein is dissected free, isolated, and divided with a stapler introduced through the utility incision.

The bronchus is exposed next by retracting the lobe cranially. It is dissected free from the adjacent pulmonary artery. At this time, care is taken to identify the origin of the middle lobe bronchus (for a right lower lobectomy) and ensure it is not inadvertently included in a potential staple line.

At this point, the lower lobe bronchus can be divided using a stapler passed through the utility incision. Alternatively, the anterior part of the oblique fissure can be completed by positioning the tip of the stapler on top of the previously exposed pulmonary artery. This allows further exposure of the pulmonary artery, including identification of the apical segmental branch. The arterial trunk (including the apical segmental branch) is dissected free by passing an instrument around it, usually via the inferior port. A vessel loop may aid placement of a stapler and division of the entire arterial trunk supplying the lower lobe. Sometimes it is easier to divide the basilar and apical segmental arteries separately.

The oblique fissure is completed at the end of the procedure and the lobe removed. If the bronchus was not taken before division of the pulmonary artery, it may be divided at the same time as the fissure.

Lymph node dissection

A systematic mediastinal lymph node dissection is performed to ensure adequate staging. A combination of blunt and sharp dissection is achieved using endoscopic suction, energy devices, or diathermy. Long, curved thoracoscopic grasping forceps, such as the D'Amico lymph node grasper (Scanlan), are used to facilitate exposure or grasp lymph nodes.

To access the right paratracheal region (stations 2R and 4R), the mediastinal pleura is incised above and below the azygos vein, parallel to the superior vena cava. The dissection begins at the tracheobronchial angle and progresses upward. The entire fat pad containing nodes is removed *en bloc*.

To approach the subcarinal and paraesophageal regions (stations 7 and 8) on the right, the lung is retracted anteriorly and the posterior mediastinal pleura incised parallel to the bronchus intermedius to the level of the azygos vein. The subcarinal space is exposed, and all station 7 and 8 lymph nodes including the surrounding fat are removed *en bloc* so that the carinal bifurcation and the left main bronchus are visualized.

Access to the subcarinal space from the left is slightly more awkward. It can be approached in a similar manner to the right, particularly if a lower lobectomy has been performed, as this allows better visualization of the posterior hilum. The posterior aspect of the left main bronchus can be tracked down into the subcarinal space. Alternatively, the subcarinal space can be approached from the front. The left main bronchus is identified, and dissection continues proximally by freeing the superior pulmonary vein (or its stump following upper lobectomy) and the posterior pericardium from the bronchus until the station 7 lymph nodes are seen. Station 8 lymph nodes can be dissected free at the same time.

On the left, lymph nodes are removed *en bloc* from the aortopulmonary and para-aortic region (stations 5 and 6) relatively easily following division of the overlying mediastinal pleura. Care should be taken to avoid damage to the recurrent laryngeal and phrenic nerves. Inferior pulmonary ligament nodes (station 9) are straightforward to resect and are usually taken at the time of division of the ligament during the initial hilar dissection.

FUTURE DIRECTIONS

VATS lobectomy appears to offer equivalent oncological results as open surgery for lung cancer with fewer side effects. There

remains much debate about the specific VATS approach, but there is no evidence that one technique produces superior outcomes to another.⁹ Robotic-assisted thoracic surgery (RATS) shows some promise but again does not appear to have a significant advantage for patients over conventional VATS.³² RATS may, however, allow more patients to undergo minimally invasive surgery, as surgeons who have struggled with VATS are more likely to be comfortable with a robotic approach.

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Other minimally invasive abdominal/retroperitoneal procedures



Joel M. Babb, *First Successful Organ Transplant*, 1996. Oil on linen, 70 × 88 inches. Warren Anatomical Museum Center for the History of Medicine, Francis A. Countway Library of Medicine, Harvard Medical School, Cambridge, MA. (Image courtesy Francis A. Countway Library of Medicine, Harvard Medical School.)

In late 1954, twenty-three-year-old Richard Herrick returned to his native Boston after recently being discharged from the Coast Guard intending to reconnect with his family, including his twin brother Ronald. However, their joyous reunion would be short lived. Soon after his arrival, Richard was diagnosed with kidney disease, which at that time was often lethal. As luck would have it, several young doctors and scientists working nearby at the Peter Bent Brigham Hospital and Harvard Medical School were developing ways to transplant healthy kidneys to replace failing organs, and they

were searching for a set of twins to accept the first operation. After determining the Herrick brothers as suitable subjects, a team led by plastic surgeon Joseph E. Murray, and including John Merrill (nephrologist), J. Hartwell Harrison (urologist), Gustave Dammin (pathologist), and Harvard surgery chairman Francis D. Moore, performed the first successful kidney transplant on Richard and Ronald on December 23, 1954. Dr. Murray would go on to pioneer the use of anti-rejection drugs, resulting in the first transplantation from an unrelated cadaver donor in 1962. His work on organ

transplantation earned him the Nobel Prize in Physiology or Medicine in 1990.

In the mid-1990s, artist Joel Babb was commissioned to commemorate the first successful human organ transplant by three of the doctors who took part in the momentous surgery. The subject of surgery held particular importance for the artist as well, for he had undergone a heart operation when he was a child that proved a formative experience. Based on historical photographs and interviews with the surgeons, Babb reconstructed the event in minute detail, down to the patterns of light in the brick wall separating

the two patients. His composition was drawn from sketches provided by the surgeons and his own photographs of the tools used in the procedure, which one of the original surgeons had laid out for him in an operating room at the hospital. The completed painting now hangs in the Countway Library at Harvard Medical School, opposite a work by artist Robert Hinckley illustrating the first use of ether in Harvard's Ether Dome in 1846. Later, in 2015, Babb went on to paint the first successful full-face transplant in the United States at the Brigham and Women's Hospital for the participating surgeons.

The role of robotics in minimally invasive urologic surgery

OSTAP DOVIRAK AND ANDREW A. WAGNER

HISTORY AND DEFINITION OF SURGICAL ROBOTICS

The U.S. Food and Drug Administration first approved the da Vinci robot for use in general laparoscopic surgery in 2000, followed by clearances in 2001 for radical prostatectomy, and in 2005 for other urological and gynecological procedures. Since then, surgeons have reported on the use of robot assistance to perform essentially every laparoscopic surgical procedure.

The da Vinci robotic surgery system currently used in minimally invasive surgery is considered a *master-slave robot*. Thus, the robot does not perform autonomously but is under direct control by the surgeon (master), who is controlling the robot from a control console and is not in direct physical contact with the robot or patient. The surgeon controls the robotic arms (camera and instruments) using finger toggles, the motions are processed by the console's computer, and the data are sent digitally to the bedside robotic cart, which then interprets the data and makes corresponding movements.

ADVANTAGES OF ROBOTICS

The surgical robot is ideally suited for use in minimally invasive reconstructive surgery, and by design, overcomes several of the obstacles of traditional laparoscopic surgery. For example, the laparoscopic camera is held stable by a robotic arm controlled at the surgeon's console. This removes the issues of surgeon fatigue, camera-holder inexperience, and camera motion. Moreover, the da Vinci system incorporates a high-definition three-dimensional (3D) view using two separate lenses incorporated into one telescope offering up to 10× magnification. The two views are fed back to the surgeon console as a 3D image.

The robotic instruments have improved maneuverability when compared to standard laparoscopy based on additional degrees of freedom offered by the "wristed" system. The robot also filters out fine tremors, allowing for more precise dissection, and allows the surgeon to adjust movements for the scale of the procedure being performed (motion scaling).

ROBOTICS IN UROLOGY

The advantages of robotic surgery over laparoscopy have translated not only into increased surgeon comfort, but more precise dissection and shorter time for tasks requiring suturing and knot-tying, such as anastomoses and organ reconstruction. Urologists have taken the lead with respect to robot-assisted surgery, utilizing it most effectively in urologic reconstructive procedures such as radical prostatectomy, partial nephrectomy, pyeloplasty, and ureteral reimplantation. Purely extirpative procedures such as radical nephrectomy and adrenalectomy, in general, do not require the visualization and dexterity improvements that robotics offers and are still most commonly performed using pure laparoscopy.

PROSTATE SURGERY

Robot-assisted laparoscopic radical prostatectomy

Approximately one-third of all male cancers are attributed to prostate cancer.¹ Such high prevalence and the morbidity of traditional open radical prostatectomy (OP) (bleeding, impotence, and incontinence) resulted in a push for improved surgical techniques. Radical prostatectomy, the removal of the prostate and the seminal vesicles for the

treatment of localized prostate cancer, is a notoriously difficult operation involving division of the urethra and bladder neck, dissection of the prostate off the anterior rectal wall, and reconstruction of the urinary tract using a vesicourethral anastomosis. The initial experience with minimally invasive laparoscopic prostatectomy was at Johns Hopkins in 1991; however, the operative time and complications were excessive, and the approach was abandoned.² The technique was reexamined and refined by Guillonnet and Vallancien in the late 1990s, resulting in a reproducible procedure, albeit one requiring significant laparoscopic skill.³ Because of the intense learning curve, in particular, the difficulty of laparoscopically suturing the vesicourethral anastomosis, pure laparoscopic prostatectomy did not ever really become commonplace. In 2002 Menon published his experience with robot-assisted prostatectomy, demonstrating some of the advantages that robotics was able to offer the traditional open surgeon. Despite the lack of randomized comparative trials between open and robotic surgery, the advantages of 3D visualization and wristed instrumentation helped the robot-assisted laparoscopic prostatectomy (RALP) to become the treatment of choice for prostate cancer. Currently, four out of five prostatectomies in the United States are performed robotically, a trend primarily driven by patient and surgeon preference.¹

OPERATIVE OUTCOMES

The benefits of RALP over OP become apparent when comparing intraoperative blood loss and postoperative length of hospital stay. Due to improved visualization and increased intra-abdominal pressure from pneumoperitoneum, patients undergoing RALP have significantly lower intraoperative blood loss and risk for blood transfusions.^{3–5} For example, one institution study reported blood loss in a prospective analyses of OP and RALP of 910 mL and 153 mL, respectively.⁶ Similarly, the risk of transfusion was much higher for OP with 67% of patients transfused versus none in the RALP group.⁶ Also, RALP patients benefit from a shorter length of hospital stay compared to open surgery, with over 95% being discharged on postoperative day 1. Postoperative pain, however, is reported to be similar between surgical approaches, with almost identical pain scores and similar morphine sulfate equivalent requirements.⁷

The complication rate is overall lower for RALP (10.6%) when compared to OP (15.8%).⁸ However, there is a considerable learning curve while surgeons become proficient with the robotic approach. In general, to achieve outcomes comparable with their open surgical experience, a surgeon must perform anywhere from 8 cases to as many as 200 cases, and experts believe surgical quality continues to improve well past several hundred cases.⁴ RALP complication rates, positive surgical margins, and quality of life measures also tend to improve as surgeons' volume increases.⁸

ONCOLOGIC OUTCOMES

There is a general consensus that the goals of radical prostatectomy in order of importance are controlling cancer,

maintaining urinary continence, maintaining erectile function, and minimizing perioperative morbidity.⁴ Historically, oncologic outcomes have been found to be similar between open and robotic approaches. In lieu of long-term comparative trials, margin status is often considered a surrogate for cancer control after radical prostatectomy. Multiple studies have demonstrated the risk of positive surgical margin is comparable between OP and RALP.⁵ For example, Tewari et al. reported a similar overall surgical margin status of 24.2% for OP and 16.2% for RALP.⁹ No significant difference in positive surgical margins was seen in more advanced pT3 cancer, OP 42.6% and RALP 37.2%.⁹ With regard to the risk of PSA-recurrence (biochemical recurrence), Badani et al. reported a 5-year actuarial biochemical-free survival of 84% in a large series.¹⁰ This equals the outcomes of 5-year biochemical-free survival of 82% after OP reported by the Memorial Sloan Kettering Cancer Center.⁴

FUNCTIONAL OUTCOMES

During radical prostatectomy, there is trauma to both the internal urinary sphincter and the neurovascular bundles responsible for erectile function; thus, the most pronounced postoperative morbidities are urinary incontinence and erectile dysfunction. In general, continence rates are considered similar between OP and RALP. Depending on the definition of continence, both OP and RALP have continence rates defined as 0–1 incontinence pad daily at 12 months after surgery, in the high 90th percentile.^{4,5} Outcomes for erectile function in the age-matched categories appear to favor the robotic approach; however, robust prospective data are lacking. Kim et al. reported that the number of patients having erection sufficient for intercourse at 24 months after surgery was 83.8% in the RALP group and 47.5% in the OP group.¹¹ Krambeck et al. reported potency rates to have no statistical difference, RALP 70.0% versus OP 62.8%.¹² Both OP and RALP are incredibly nuanced operations, where the anatomy and relationships of external sphincter, neurovascular bundles, prostatic capsule, and bladder neck often present the surgeon with competing priorities of removing the cancerous organ while maintaining continuity of adjacent structures. Because of this, meticulous dissection and nuanced decision-making are often necessary to allow for optimal functional outcomes. As expected with this type of surgery, experience and training are likely far more important variables than surgical approach, and health-related quality of life outcomes tend to improve with surgeons' experience as well as case volume.

Simple robotic prostatectomy

Advances in the field of endoscopy enabled urologists to utilize a variety of cystoscopic approaches for management of benign prostatic hyperplasia (BPH). Management of large glands, greater than 80 gm, however, remains one of the indications for simple prostatectomy—removal of the

transitional zone while preserving the peripheral zone of the prostate. The first laparoscopic simple prostatectomy (LSP) was described by Mariano et al. in 2002.¹³ Since then, numerous studies have shown outcomes from LSP to be comparable to the gold standard—open simple prostatectomy (OSP). In 2008, Sotelo et al. demonstrated feasibility of robotic simple prostatectomy (RSP), which was popularized due to benefits of improved visualization and decreased bleeding over the open approach.¹⁴

Comparative studies show that minimally invasive (MI) approaches to simple prostatectomy result in similar improvement in maximum urine flow and improvement in IPSS (International Prostate Symptom Score) when compared to open simple prostatectomy. In addition, such benefits as shortened hospital stay, decreased blood loss, and shorter duration of catheterization after MI surgery argue in favor of these approaches as a safe treatment option of BPH.¹⁵

KIDNEY SURGERY

Robot-assisted radical nephrectomy

Since the early 1990s, the benefits of laparoscopic kidney surgery compared to open surgery have been fairly obvious, and numerous centers have demonstrated shorter hospital stay, less blood loss, decreased narcotic use, and quicker return to normal activity.^{16–18} Current recommendations from the European Association of Urology for patients with cT2 kidney tumors who are not candidates for nephron-sparing surgery are to undergo laparoscopic radical nephrectomy for the benefit of lower morbidity compared to open nephrectomy (ON).¹⁹

As radical nephrectomy, however, is purely an extirpative procedure, the advantages of robotics (improved ability of intracorporeal suturing and reconstruction) are not as crucial to the surgeon. Initially adopted by Guillonnet in 2001, robotic radical nephrectomy (RRN) failed to demonstrate benefits over the traditional laparoscopic approach.^{20,21} Nevertheless, some surgeons advocate the use of robotics in radical nephrectomy as a training procedure in preparation for more challenging upper tract procedures.²¹ A major drawback to RRN as with most robot-assisted surgeries is the cost implications. Compared to LN, RRN conferred \$11,267 more in total charges and \$4,565 in hospital-stay charges without improving patient morbidity.²² Until clear evidence supporting superiority of RRN over less-expensive extirpative modalities is gathered, LN will remain the gold standard for uncomplicated masses.

One recent application of robotics in the radical nephrectomy setting involves complicated cases of renal vein and vena caval tumor thrombus. There have been small series of complete vena cava control followed by tumor thrombus removal and caval reconstruction. It is likely that in the hands of very experienced robotic surgeons, this approach will become more commonplace.²³

Partial nephrectomy

In recent years, frequent use of cross-sectional imaging has increased the incidence of incidentally detected small renal masses.²⁴ Open nephron-sparing surgery (partial nephrectomy, OPN) offered patients good long-term local cancer control and preservation of renal function.^{25,26} Laparoscopic partial nephrectomy (LPN) was able to reproduce the technical aspects of tumor resection and reconstruction; however, LPN often involved longer warm ischemia times and a lengthy learning curve due to the difficulty of intracorporeal suturing.²⁷ Gill et al. reported warm ischemia time for LPN of 30.7 minutes compared to 20.1 minutes for OPN. There was also a question of increased intraoperative complications in these patients (1.8% versus 1.0%), when compared to open surgery, with odds of secondary procedure 3.05 times higher for LPN.²⁷ With these issues in mind, there was an opportunity for robotic technology to offer more straightforward kidney reconstruction and improved visualization for partial nephrectomy with appropriate experience, surgical volume, and training.²⁸

PERIOPERATIVE OUTCOMES

Perioperative indicators of quality after partial nephrectomy include blood loss, warm ischemia time, and complication rates. It appears that in experienced hands, robotic partial nephrectomy (RPN) can offer a shorter warm ischemia time than laparoscopic surgery.^{29,30} Mean warm ischemia times for RPN vary from 14.5 to 35.3 minutes, and are 1.1–9.5 minutes faster than LPN.³⁰ However, the rates of complications, estimated blood loss, length of hospitalization, conversion to open approach, or operative times are similar among laparoscopic and robotic partial nephrectomies.^{29,30} Few studies compare surgical outcomes between open and robotic partial nephrectomies, but when comparing OPN to LPN, longer ischemia time and longer learning curve are required with LPN.³¹ Morbidity between LPN and OPN seems to be similar, with slightly higher rates of urine leak in LPN and higher rate of postoperative bleeding.³¹ A meta-analysis by Porpiglia et al. showed bleeding rates of 3.2% for OPN versus 5% in LPN and urine leak rates of 3.9% for OPN versus 4.2% in LPN.³¹ These results may not be generalized to low-volume surgeons, and a caseload of greater than 200 LPNs may be necessary to significantly reduce postoperative complication rates.³¹

ONCOLOGIC OUTCOMES

RPN is able to yield excellent oncologic control in experienced hands. Reported positive cancer margins are low at 2.7% and are similar to the reports from large LPN series.^{29,32} Cancer-free survival at 3 and 5 years is also comparable to open and laparoscopic partial nephrectomy at 98.9%.³³ Long-term follow-up data are still needed to assess cancer-specific outcomes in this population group.

FUNCTIONAL OUTCOMES

Recovery after renal surgery can be separated into perioperative results, subacute recovery, and subsequent recuperation to baseline functional status. The overall average hospital stay varies from 2–5 days and is independent of robotic or laparoscopic approach,^{29,30,34} OPN, however, requires a longer hospital stay, a higher narcotics requirement, and slower convalescence when compared to LPN.³¹ There has been recent interest in the area of postoperative quality of life and overall length of recovery. The initial use of validated questionnaires suggests full recovery after 4–8 weeks despite the minimally invasive approach.³⁵ Renal function outcomes as a measure of postoperative creatinine and glomerular filtration rate appear to be similar across interventional modalities.^{31,36}

BLADDER SURGERY

Robotic radical cystectomy

Bladder cancer was estimated to affect 74,000 people in 2015 and constitutes 2.7% of all cancer deaths in the United States.³⁷ While transurethral resection is the mainstay treatment for superficial bladder tumors, radical cystectomy is indicated for the management of muscle-invasive tumors (pT2 or higher stage). Open radical cystectomy (ORC) and urinary diversion has been the gold standard treatment of invasive bladder cancer; however, as urologists became more experienced using minimally invasive approaches for prostatectomy, laparoscopic and robotic-assisted radical cystectomy (RARC) have been used more frequently. RARC has the potential of offering benefits common to minimally invasive surgery, including decreased blood loss, improved visualization, and less postoperative pain.^{38,39}

OPERATIVE OUTCOMES

Radical cystectomy with urinary diversion is a complicated and morbid procedure typically carried out in an older patient population with multiple comorbidities. It is no surprise then that an exceptionally high rate of complications is seen in the perioperative period. Most prospective series of RARC see complication rates similar to ORC. For example, a prospective randomized study comparing open to robotic cystectomy found that at 90-day follow-up, the complication rate (Clavien grades II–V) was 62% for RARC and 66% for the ORC cohort.⁴⁰ These results are echoed by other studies.⁴¹ In a meta-analysis by Ishii et al., no statistical difference existed in overall complication rate between ORC and RARC.³⁹ A low-grade complication rate (Clavien grade I–II) was reported to be similar between robotic and open cohort, however, a significantly higher number of high-grade complications (Clavien III–IV) occurred in ORC. Mortality was at 2.2% in ORC compared to 0.35% in RARC groups.³⁹ One theoretical method of lowering

the complication rate is to minimize bowel manipulation at the time of urinary diversion by performing the urinary diversion totally intracorporeally. High-volume centers are just beginning to accumulate data regarding this approach; however, to date there appears to be no distinct advantage over the standard extracorporeal diversion. Results from the International Robotic Cystectomy Consortium found similar overall complications but found significantly fewer gastrointestinal complications in the intracorporeal group.⁴²

Despite similar complication rates between minimally invasive and open cystectomy, several perioperative advantages are observed with the robotic approach. Galich et al. reported lower estimated blood loss and shorter hospital stay. Other studies, including the randomized trial by Bochner et al., also showed less blood loss.^{38,40} The robotic approach requires longer operative time and higher cost of hospitalization.^{38,39,43} Clearly, more work is required to reduce complications after this operation and improve outcomes. Of note, significant robotic experience is mandatory prior to embarking on RARC, and only high-volume centers are performing RARC with intracorporeal urinary diversion.

ONCOLOGIC OUTCOMES

Few studies have evaluated longer-term cancer control outcomes comparing ORC to RARC. The Cleveland Clinic and USC groups found oncologic outcomes at 12 years after minimally invasive cystectomy similar to published rates after ORC.⁴⁴ Positive margin rates and lymph node yields can be used as surrogates for cancer control until more comparative data are available. To date, two randomized trials have demonstrated similar margin rates (about 5%) and pelvic lymph node yields between open and robotic approaches.^{40,45} Margin status is believed to correlate with pathologic tumor stage. In RARC, positive margins are reported at 1.5% for pT2, 8.8% for pT3, and 39% for pT4 bladder cancer and are similar to surgical margins reported for advanced invasive bladder cancer in ORC series.⁴⁶

CONCLUSION

Among all surgeons, urologists have historically had the most experience with robot-assisted techniques. Robotic prostatectomy is commonplace and safe in appropriately trained hands. Robotic partial nephrectomy for kidney tumors is becoming a standard approach, and robotic cystectomy with urinary diversion, although currently not the standard of care, will likely surpass open surgery as experience is gained. Advantages to these approaches include reduced blood loss, better visualization, and less perioperative morbidity. The complication risk is still similar when compared to open surgery, and perhaps most importantly, patient results with robotic surgery depend heavily on surgeon training and experience.

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Laparoscopic nephrectomy for malignancy

AARON LAY AND JEFFREY A. CAEDDU

INDICATIONS

There were an estimated 63,920 new cases of kidney and renal pelvis cancers in the United States in 2014,¹ the majority of which were renal cell carcinomas (RCCs). Radical nephrectomy was introduced in 1963 for the treatment of RCC.² In the past two decades, nephron-sparing surgery has become the standard for treatment of small localized renal masses ≤ 4 cm.³ However, for larger tumors and in carefully selected cases with metastatic disease, radical nephrectomy is still the gold standard treatment.

The first reported case of laparoscopic nephrectomy was presented by Clayman et al. in 1991.⁴ With refinement of technique and increased experience, surgeons are now able to remove kidneys with large tumors greater than 10 cm and tumors with renal vein involvement laparoscopically. However, there are several important patient factors and tumor characteristics to consider prior to proceeding. The laparoscopic approach may be difficult for patients with extremely large tumors (greater than 15 cm) due to limited working space, while cases with renal vein tumor thrombus extending into the inferior vena cava should be performed open for optimal control of the great vessels. In addition, patients with prior history of ipsilateral renal surgery, extensive intra-abdominal surgery, and extensive perinephric inflammation may have an increased risk for conversion to open surgery. Careful examination of cross-sectional imaging is required to define the renovascular anatomy. If the adrenal gland is not involved by local invasion of an upper pole tumor or by a metastatic deposit, the gland can be spared during surgery.

Laparoscopic radical nephrectomy can be performed via a transperitoneal or a retroperitoneal approach. The hand-assisted technique can also be utilized. This chapter describes the more widely used transperitoneal approach.

PATIENT POSITIONING AND TROCAR PLACEMENT

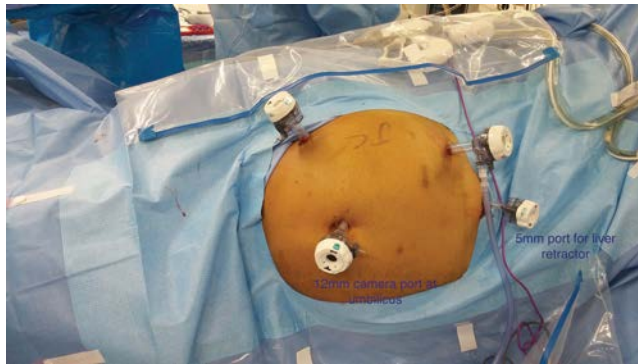
After induction of general anesthesia, the patient is positioned in a 30° modified decubitus position with the ipsilateral side up. An orogastric tube is placed along with a bladder catheter. The hip is positioned over the break in the table, and the table is flexed approximately 30° to widen the space between the costal margin and the iliac crest. The ipsilateral arm is then placed at the patient's side, secured, and padded. The bottom leg is bent slightly, and pillows are placed between the legs. All potential pressure points are carefully padded. An axillary roll may be needed to prevent brachial plexus injury.

The patient is then secured to the operating table with wide tape over the chest, hips, and legs. The bed is rotated to ensure the patient is safely secured prior to surgical preparation and draping. The surgical field is prepared from the nipples to the pubis and from the paraspinal muscles to the contralateral rectus muscle. The surgeon and the camera holder face the patient's abdomen, while the scrub nurse and any other assistants face the patient's back.

The peritoneum is insufflated to 15 mm Hg with a Veress needle inserted at either the umbilicus or the midclavicular line just off the costal margin. Generally, three ports are sufficient to perform the case. For right-sided cases, an additional port for the liver retractor is needed. For larger tumors, an additional port may be placed laterally for upper pole and hilar dissection.

A 12 mm camera port is placed through a periumbilical incision. An optical trocar should be used to allow for endoscopic visualization while the trocar is introduced. The patient is then rotated toward the surgeon to a flank position. A second 12 mm port is placed along the ipsilateral midclavicular line just caudal to the first port.

(a)



(b)



Figure 107.1 (a) Port positioning for right sided laparoscopic nephrectomy. (b) Port positioning for left sided laparoscopic nephrectomy in an obese patient. Ports are shifted laterally.

The third 12 mm port is then placed just below the costal margin, one-third of the way between the xiphoid and the umbilicus. For right-sided cases, a 3 mm or 5 mm port is placed below the xiphoid process for an eventual liver retractor (**Figure 107.1a**). In obese patients, the ports may need to be moved laterally and superiorly to ensure that the instruments can reach and complete the dissection (**Figure 107.1b**).

OPERATIVE STEPS

Exposure of the retroperitoneum

Electrosurgical scissors and 5 mm atraumatic forceps are used to incise the ipsilateral white line of Toldt. The colon and mesentery are mobilized and dissected medially to expose Gerota's fascia and the retroperitoneum (**Figure 107.2**). On the right side, this is carried out from the right common iliac artery up to the hepatic flexure. The right triangular and anterior coronary ligaments of the liver may need to be divided to aid in liver retraction. A 3 mm or 5 mm grasper is then placed through the subxiphoid trocar to lift the edge of the liver away from the retroperitoneum and is gently secured to the body wall.

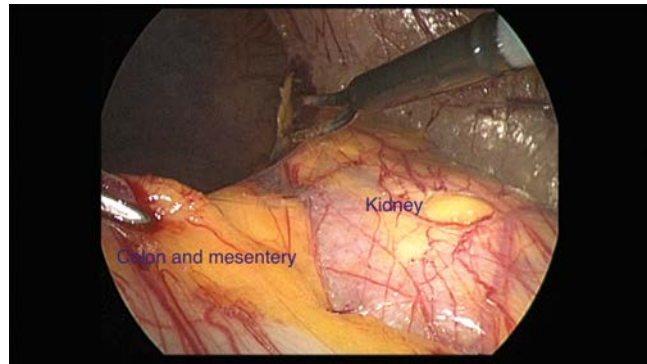


Figure 107.2 The colon is medialized to expose Gerota's fascia and the retroperitoneum. Note the different hue in mesenteric fat, which helps denoting the correct plane of dissection.

When mobilizing the colon, grasp the peritoneum and mesenteric fat with atraumatic forceps to provide gentle traction. The colonic mesenteric fat has a more pronounced yellow hue that is used to differentiate from Gerota's fascia and retroperitoneal fat (**Figure 107.2**). Use electrosurgical scissors to divide small vessels and achieve hemostasis. This dissection plane is generally avascular, and blunt dissection can be used with a blunt-tipped irrigator-aspiration device. The duodenum is then sharply mobilized medially until the vena cava is visualized.

For a left-sided radical nephrectomy, the white line of Toldt is incised from the left common iliac artery to the splenic flexure. A retractor is not necessary for a left-sided procedure, though it is important to mobilize the spleen medially to expose the upper pole of the left kidney by dividing the splenorenal ligament and the splenophrenic attachments. The colon and mesentery should be rolled medially to the level of the anterior surface of the aorta.

To avoid inadvertent thermal injury, be careful when using electrocautery near bowel. Be alert for a retrocecal appendix on a right-sided case to avoid injury. Also, avoid creating mesenteric windows that could allow for internal herniation in the future.

Identification of the gonadal vein and the ureter

After adequate bowel and mesenteric mobilization, the gonadal vein should be seen easily. Gerota's fascia is then incised just lateral to the gonadal vessels to sweep them medially and preserve them whenever possible. This maneuver helps in identification of the ureter within the retroperitoneal fat (**Figure 107.3**). Typically, the ureter is located lateral and posterior to the gonadal vein. The ureter along with retroperitoneal fat is then retracted laterally. The ureter is not transected at this time to aid in the exposure and dissection of the renal hilum.

Occasionally, the identification of the ureter can be difficult. If this is the case, systematic inspection of the retroperitoneum is necessary, starting at the great vessels and

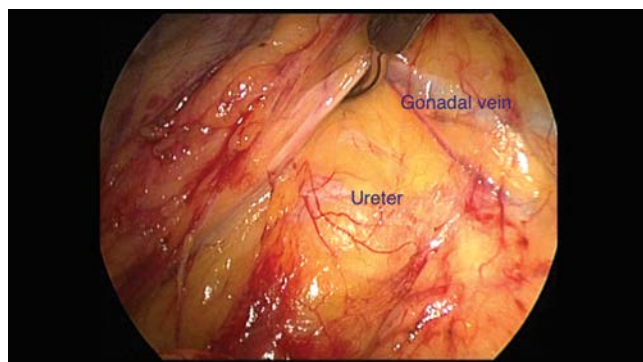


Figure 107.3 Identification of the ureter within the retroperitoneum, which is typically lateral and posterior to the gonadal vein.

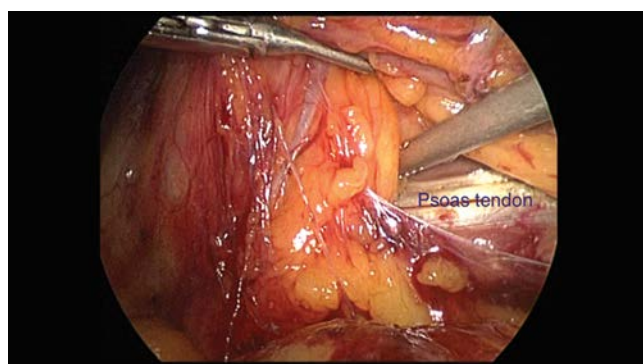


Figure 107.4 Blunt dissection is performed to identify psoas fascia, which is then dissected free from the posterior surface of Gerota's fascia.

working laterally. The ureter can be located more medially than anticipated. Use atraumatic forceps to stroke and pinch the retroperitoneal fat to look for ureteral peristalsis. Alternatively, the ureter can be found reliably caudally where it crosses the iliac vessels.

The ureter along with the retroperitoneal fat is then retracted laterally and anteriorly until psoas fascia is encountered. The plane between Gerota's fascia and psoas fascia is generally avascular, and dissection is performed bluntly with an irrigator-aspiration device (Figure 107.4). To get adequate lift of the specimen, the peritoneum and Gerota's fascia around the upper pole should be incised. While the specimen is lifted off the psoas fascia, the medial attachments are divided meticulously with electrocautery, working superiorly toward the renal hilum. This dissection is carried out until the inferior edge of the renal vein is encountered.

Dividing the hilum

Securing the renal hilum is the most important and dangerous step of this operation. In our experience, dividing the hilum *en bloc* with a vascular stapler is safe and

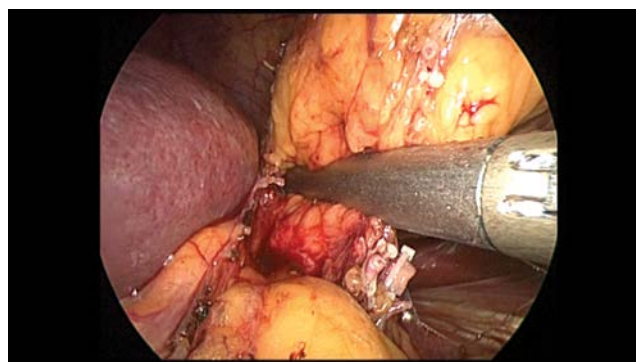


Figure 107.5 Division of the renal hilum is performed *en bloc*. Ensure the superior edge of the renal hilum is safely incorporated within the vascular stapler.

efficient. It has not been shown to increase the risk of formation of arteriovenous fistulae.⁵ As such, the individual renal arteries and veins are not dissected to minimize risk of inadvertent vascular injury. Gerota's fascia superior to the renal hilum is incised and carefully dissected to rule out the presence of an upper pole renal artery. With this technique, it is important to ensure that the superior edge of the renal hilum is safely incorporated within the vascular stapler. Exposure of the renal hilum is aided by lifting the specimen laterally and superiorly. A 10 mm endovascular GIA stapler is passed through the lower quadrant port. The jaws of the stapler are advanced over the hilum without resistance and closed to occlude the hilum, and the stapler is then fired (Figure 107.5).

If the tumor is very large, an additional 5 mm port may be placed laterally at the level of the camera port. An instrument can be used to help lift the specimen for hilar exposure. The port can also be used for upper pole dissection.

Dividing superior and lateral attachments

After the renal hilum is secured, the upper pole dissection should be completed. As mentioned previously, the adrenal gland is spared unless it is involved by local extension of an upper pole tumor or by a metastatic deposit. The dissection is performed just lateral to the adrenal gland to leave as much perinephric fat around the superior pole of the kidney as possible. For a left-sided case, preserve the adrenal vein as it branches from the renal vein and do not incorporate it in the vascular stapler.

Attention is then turned to the caudal and lateral attachments. The ureter is transected between clips, and the retroperitoneal fat off the lower pole of the kidney is divided to the body wall laterally. Retract the specimen medially, and divide the remaining lateral attachments to complete the radical nephrectomy.

After mobilization, the specimen should be moved above the liver or spleen or into the pelvis to allow inspection of the renal fossa for hemostasis. Lower the intra-abdominal

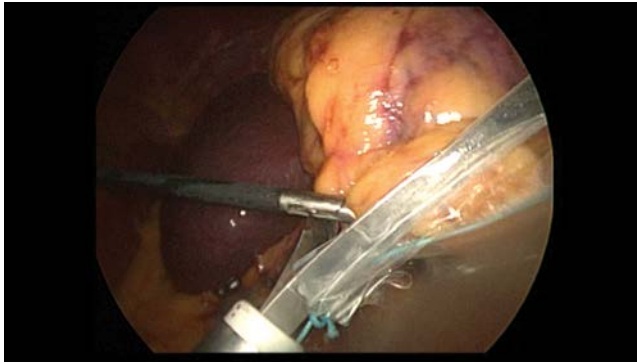


Figure 107.6 Use gravity to aid placement of specimen into the bag. The bag should be closed under vision to ensure the specimen is safely captured and no bowel is entrapped.

pressure to 5 mm Hg and observe the operative field. Close attention is paid to the renal hilum, the adrenal bed, and any other potential sites for bleeding.

Specimen removal and closure

A 15 mm endoscopic specimen bag is used to remove a radical nephrectomy specimen. The umbilical port is removed and digitally dilated. The device is then placed directly through the skin, and the specimen is extracted through a periumbilical incision. In obese patients, the device is placed through the lower quadrant port and extracted through an extension of that incision.

The specimen is first grasped and placed above the spleen or liver. The device is introduced into the abdomen and deployed. Use gravity to drop the specimen into the bag (**Figure 107.6**). After pulling the drawstring, the ring should be closed under direct vision to ensure no bowel is entrapped.

The ports are then removed under direct vision. A 4–6 cm periumbilical incision is made to extract the specimen. Open the fascia and extract the specimen by pulling on the string, exerting gentle traction to get the bag through the incision. Extend the incision as

necessary to avoid using excessive force and tearing the bag. There is no role for morcellation in radical nephrectomy for malignancy. Close the fascia and incision in a standard fashion.

POSTOPERATIVE MANAGEMENT AND COMPLICATIONS

Typically, a minimal amount of IV narcotics is needed to control pain postoperatively, and a clear liquid diet is started following surgery. The patient is encouraged to ambulate, and the urethral catheter is removed the next day. The diet is then advanced as tolerated. Postoperative antibiotics are not necessary. Most patients are discharged on the first or second postoperative day.

The potential complications of laparoscopic radical nephrectomy are well described. Large series have reported the complication rate to be around 10%.⁶ Access-related injuries include port-site hernias, abdominal wall hematomas, vascular injuries, or organ injuries. Though rare, the surgical team should be prepared for emergent conversion to an open procedure secondary to vascular injuries or injuries to other organs. A general laparotomy set with vascular clamps and instruments must be readily available for each case.

Postoperative complications can include wound infections, incisional hernias, prolonged ileus, pneumonia, pulmonary embolus, and atrial fibrillation. Paraesthesias and brachial nerve plexus palsy can occur from improper patient positioning. This can be avoided by minimizing pressure points and properly securing and padding the patient.

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Laparoscopic donor nephrectomy

DANIEL M. HERRON

INTRODUCTION

Laparoscopic donor nephrectomy first became commonly utilized in the late 1990s. The availability of a minimally invasive approach has made kidney donation much more appealing to many donors and has the potential to increase the pool of donors. Laparoscopic donor nephrectomy has become the preferred operative approach for living kidney donation in most transplant centers. At our institution, we have been performing laparoscopic donor nephrectomy since 1996.¹

Laparoscopic donor nephrectomy must be performed with meticulous attention to technique in order to achieve an acceptably low rate of complications. In our first 500 cases, our group reported a mean operative time of 3.5 hours, a conversion to open rate of 1.8%, and an immediate graft survival rate of 97.5%.² The most common complication is bleeding, with an incidence of 5.4% in our series. In our center, we have found that outcomes correlate with surgeon experience: Operative time decreased by 87 minutes after the initial 150 cases, and the overall complication rate progressively diminished with each surgeon's increasing lifetime experience.²

PREOPERATIVE EVALUATION

A donor candidate must be rigorously evaluated by a specialized multidisciplinary donor evaluation team. While such teams will necessarily vary from institution to institution, they typically include a transplant nurse, social worker, internist, and/or nephrologist. Vascular imaging is routinely performed to assess for the very common arterial and venous anatomic anomalies that may affect choice of side and operative approach. While our group initially used computed tomography (CT) angiography for all donors, we now prefer magnetic resonance angiography, as it avoids

radiation exposure and minimizes (although does not eliminate) the risk of dye-induced nephrotoxicity.³

CHOICE OF SIDE

In a patient with normal renovascular anatomy, that is, a single renal artery and vein bilaterally, the left kidney is usually preferred due to its longer renal vein, which minimizes the technical difficulty of implantation. However, it is appropriate to use the right kidney if anatomic factors suggest that it is preferred.⁴ Vascular anomalies, such as the presence of multiple renal arteries or veins, may make a kidney less appealing for donation, although organs with multiple arteries may still be safely transplanted.⁵ Size is also an important factor: In patients with significant size discrepancy between the left and right kidneys, which we arbitrarily define as one being approximately 20% larger than the other, we prefer the smaller one. Finally, the presence of benign cysts in a given kidney will make it favored for donation, so that we may leave behind the more anatomically "normal" organ. In the Mount Sinai experience, approximately 84% of our donors are left-sided.¹

CONSENT PROCESS

Living organ donation represents an unusual if not unique situation with regard to the consent process in that the patient is completely healthy and receives no physical benefit from the procedure. Because of the absence of therapeutic benefit to the patient, it is necessary to utilize a more rigorous consent process than for a general surgical procedure.⁶ In addition to our standard surgical consent forms, we thoroughly review a multipage consent document that is specific to kidney donation as performed by our group,

which outlines the specific procedure, known and unknown risks, and expected outcomes of the procedure.

OPERATIVE TECHNIQUE

Positioning the patient in lateral decubitus orientation is of great help in laparoscopic donor nephrectomy, as it facilitates exposure of the kidney and retraction of the colon and small bowel away from the field. However, it must be done with extreme care to avoid pressure injury to the trunk or extremities, and the patient must be fully secured to the operating table to avoid unintended sliding or rolling.

A vacuum beanbag is placed underneath the sheet on the operating room table for secure positioning. Sequential compression devices are applied to the patient's legs prior to induction of anesthesia, and the patient is given intravenous cefazolin. General anesthesia with endotracheal intubation is induced with the patient supine. A Pfannenstiel incision, typically 7–8 cm long and located about 3–4 cm above the pubis, is marked in ink on the patient's abdomen for extraction of the kidney. The patient is then repositioned longitudinally so that the umbilicus is located at the bed's flex point, then is carefully rotated into the right lateral decubitus position. A roll is placed underneath the right axilla to minimize pressure on the right shoulder. There should be enough space so that the surgeon can insert a hand between the patient's right arm and the axillary roll, to minimize the risk of brachial plexus injury or vascular compression. The left arm is supported by a well-padded, table-mounted arm holder, and held secure with silk tape or gauze. Alternatively, a stack of folded blankets can be placed

on top of the lower arm to create a platform to support the upper arm; this needs to be secured with belts or gauze and tape as required. The right (bottom) leg is bent and the left (upper) is left straight, with one to two pillows between them for padding. After the bed is flexed to open up the left flank space, suction is applied to the vacuum beanbag to secure the positioning. Finally, the patient is secured in place with the belt and silk tape applied to the rail, using towels to protect the skin from tape burns as needed (**Figure 108.1**).

Initial laparoscopic access is obtained using a 5 mm optical viewing trocar and a 0° laparoscope. The trocar is placed approximately 3 cm inferior to the costal margin in the mid-clavicular line. We do not use a Veress needle for insufflation prior to optical trocar access. This subcostal trocar will be used as the camera port for the remainder of the procedure. The 0° laparoscope is replaced with a 30° or 40° laparoscope for the remainder of the operation. A 5 mm trocar is inserted at the level of the umbilicus, 2–4 cm lateral to it; this will serve as the primary trocar for the surgeon's left hand. A 12 mm trocar is inserted midway between this trocar and the anterior superior iliac spine; this is the primary trocar for the surgeon's right hand for operating at or below the level of the renal hilum. Finally, a third 5 mm port is inserted laterally at the level of the umbilicus in the anterior axillary line. This trocar can be used by the first assistant for retraction or by the surgeon for access to structures superior to the renal hilum.

Dissection commences with mobilization of the left colon. For many years our group has used an ultrasonic dissector as the primary dissecting instrument, but we have recently favored the 5 mm advanced bipolar device with a Maryland dissector-shaped tip as it appears to provide better hemostasis with larger vessels. The line of Toldt is incised at the level



Figure 108.1 The patient is secured in place with the belt and silk tape applied to the rail, using towels to protect the skin from tape burns as needed.

of the mid-descending colon. This dissection plane is continued upward to the splenic flexure and downward toward the pelvic brim. The plane is expanded, gradually reflecting the colon and mesocolon medially until the ureter and gonadal vein are visualized.

A pedicle incorporating both the ureter and the gonadal vein is created. The ureter should not be stripped of surrounding tissue but should be dissected *en bloc* with the gonadal vein and surrounding retroperitoneal fat in order to minimize devascularization and thus reduce the potential for future stricture in the transplanted organ. The gonadal vein is then traced cephalad until it enters the renal vein and the small posterior branches are divided. The gonadal vein may be left in continuity with the renal vein or clipped and divided 2 cm below so that the renal vein stump can be grasped and used as a “handle” to manipulate the renal vein during dissection.

The renal vein is fully mobilized using primarily blunt dissection. The 5 mm suction-irrigator can be very effective as a dissecting instrument if used judiciously. If an energy device is used here, care must be taken to avoid any thermal injury to the vein as it is very sensitive to insult from heat. During the posterior renal vein dissection, it is critical that the surgeon looks out for anticipated or unanticipated lumbar veins, since these can bleed with great vigor if accidentally disrupted. If identified, such veins should be mobilized and divided. While it is safe to clip these vessels, we must remember that metal or plastic clips may potentially interfere with stapling of the renal vein or artery if they inadvertently get caught in the stapler jaws. For this reason, we prefer avoiding clips in this area and controlling lumbar vessels with the advanced bipolar device. The adrenal vein is identified on the cephalad aspect of the vein and divided in a similar manner, avoiding the use of clips, if possible. If it is difficult to manipulate a lumbar vessel or adrenal vein during this part of the operation, it may be helpful to place a vessel loop around it for improved retraction. We have found the 10 mm right angle dissector to be very helpful for dissection and control of these vessels.

Before we mobilize the upper pole of the kidney, we usually medialize the spleen. The lienorenal ligament is divided as are the lateral peritoneal attachments of the spleen all the way up to the diaphragm. Care should be taken with this dissection to avoid the stomach, as it may lie in very close proximity. Once the spleen is adequately mobilized, the adrenal gland should be visible adjacent to the upper pole of the kidney. A plane can be created between the adrenal and the kidney. An energy device should be used here and blunt dissection avoided as small adrenal arterial branches may extend from the renal artery directly to the adrenal gland.

Prior to fully mobilizing the renal vessels, it is prudent to open the extraction incision, as this incision may be used for additional abdominal access to apply suction or pressure if significant bleeding is encountered. The previously marked Pfannenstiel incision is opened down to the level of the fascia. Previously, we incised the anterior rectus fascia transversely and created flaps superiorly and inferiorly. However,

this resulted in occasional acute or delayed bleeding from incompletely controlled perforating vessels. We now prefer to open fascia vertically through the midline, being careful to avoid injury to the bladder inferiorly. This avoids the need to divide the rectus perforators and also simplifies subsequent fascial closure. Peritoneum can be left intact, or it can be opened and a hand-access device inserted. Regardless of which approach is preferred, the presence of the incision allows for the surgeon's hand to be rapidly inserted into the abdomen if needed for urgent retraction or hemostasis.

The last part of kidney mobilization involves the freeing of the lateral peritoneal attachments. As these are divided, starting at the inferior pole and moving cephalad, the kidney may be gradually rolled anteromedially, exposing the posterior aspect. Ultimately, this dissection will lead to the posteriorly located renal artery, which can be fully mobilized down to its origin at the aorta. The artery is commonly heavily invested with neurolymphatic tissue, which will need to be divided to optimize the length of the renal artery to be harvested. It is critical to avoid twisting the kidney around its vascular pedicle, as this may lead to compression of the artery of vein.

At this point, the kidney should be fully mobilized, held in place only by the remaining renal vein, artery, and ureteral pedicle. The back table will have been prepared for the recipient surgeon, who is called into the room at this point. Once the final go-ahead for removal of the kidney is confirmed, the ureteral pedicle is divided. The gonadal vein may be divided with the advanced bipolar device or controlled with clips and cut with scissors. The ureter should be clipped distally but may be left unclipped proximally, then divided with scissors.

The kidney is now only held by the artery and vein. At our institution we use several techniques to remove the kidney. This author prefers the hand-assisted removal, in which the surgeon's left hand is inserted through the Pfannenstiel incision and used to manipulate the kidney, while some of the other surgeons prefer to place a specimen retrieval bag around the kidney, letting the vessels emerge from its opening. The artery is taken first. It is usually best exposed by rotating the kidney medially. An Endo TA 30 stapler with a vascular load (Medtronic, Minneapolis, Minnesota) is placed across the base of the renal artery and fired. The stapler should be applied to the vessel so that the anvil side (the solid metal jaw opposite the cartridge) is most visible; this will allow the curved-over tips of the staples to be visually inspected after firing to ensure adequate firing. The exact time is noted so that the warm ischemic time may be recorded. The TA stapler does not have a cutting blade, which allows the surgeon to inspect the staple line to ensure its adequacy prior to manually dividing just above the staple line with scissors. If desired, metal clips can be placed on top of the arterial staple line for additional reinforcement prior to cutting the artery.

The kidney is then rotated laterally, exposing the vein. The same stapler is reloaded and applied to the vein as far from the kidney as possible. The stapler is fired, withdrawn, and the staple line inspected. If the staple line appears intact, the vein is then sharply divided. The kidney is then quickly removed through the extraction site, placed

into the ice-slush bath on the back table, and immediately flushed with preservative solution. Finally, hemostasis is visually confirmed, reinforcing clips are placed on the vein stump, and the trocar sites and extraction incision are closed.

RIGHT NEPHRECTOMY

The operative technique needs to be adapted in several ways if the right kidney is taken instead of the left. The patient can be positioned in left lateral decubitus position in mirror image. Trocar sites are similarly placed in mirror image, with the exception that the port near the umbilicus will need to be the 12 mm port if the stapler will be placed through it. This author places an additional 5 mm trocar either laterally or in the medial subcostal area to allow a flexible retractor to be inserted to retract the right lobe of the liver. The colon is mobilized in a similar manner, with particular care being taken to avoid injury to the retroperitoneal duodenum. Because the gonadal vein on the right

empties directly into the vena cava, it may remain *in situ* and does not need to be included with the ureteral pedicle. Similarly, there is no need to divide the adrenal vein, since it also flows directly into the vena cava. Instead of mobilizing the spleen, the right lobe of the liver needs to be mobilized by carefully dividing its lateral peritoneal attachments. The right kidney is very amenable to extraction using hand technique, since the left hand may very ergonomically be inserted through the extraction site while the right hand controls the laparoscopic instrument.

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Laparoscopic approaches to aortic vascular disease

KONSTANTINOS S. MYLONAS AND KONSTANTINOS P. ECONOMOPOULOS

INTRODUCTION

Introduced in 1966,¹ open endoaneurysmorrhaphy prevailed as the gold standard for the repair of abdominal aortic aneurysms (AAAs) despite having substantial morbidity.² In 1993, Dion et al. described laparoscopic surgery for AAAs aiming to minimize surgical trauma.³ Current approaches are the following: (1) totally laparoscopic (laparoscopic dissection and anastomosis), (2) laparoscopic-assisted (laparoscopic dissection with endoaneurysmorrhaphy via minilaparotomy), (3) hand-assisted laparoscopic, and (4) robotically-assisted laparoscopic.⁴ Trans-Atlantic Inter-Society Consensus (TASC) guidelines emphasize the merits of aortofemoral bypass over endovascular aneurysm repair (EVAR) for the treatment of aortoiliac occlusive disease (AIOD).⁵ Laparoscopy is mainly attempted in specialized centers.

A systematic search of the literature (end of search date: March 3, 2015) to identify studies on laparoscopic repair of AAAs or AIOD with more than 25 patients yielded 13 published papers. The studies were conducted prospectively at 10 different vascular surgery centers and represent populations from the United States, Canada, Germany, France, Italy, and the Netherlands.^{6–18} These data pertain to 1,596 patients with a mean age of 68.4 years.

LAPAROSCOPIC REPAIR OF AAAS

During the period of 1996–2010, 1,000 patients, ranging in age from 36 to 87 years, underwent laparoscopic repair of AAAs (**Tables 109.1 through 109.5**).^{6–14} The mean size of their aneurysms was 5.44 cm. The mean duration of the operation was 229 (90–690) minutes, clamping required 86.8 (30–286) minutes, intraoperative blood loss averaged 1,002 mL, and conversion was unavoidable in 4.7% of the

cases. A tube was placed in 61% of the patients, whereas in 39%, bifurcated grafts were implanted in order to correct concomitant iliofemoral pathology (aneurysm or AIOD).

Total laparoscopic repair of AAA: Three studies, published between 2000 and 2010, reported on 260 patients being treated for an AAA with the total laparoscopic approach.^{6–8} They were a mean age of 69.3 (46–85) years old, with a mean aneurysm size of 5.2 (4.3–9.7) cm. Of these patients, 56.5% were classified with American Society of Anesthesiologists (ASA) status II and 48.5% with ASA status III. The mean duration of the operation was 220 (145–520) minutes, clamping time was 80.8 (30–160) minutes, blood loss was 1,193 (250–4,000) mL, and conversion to open surgery was necessary in 29 cases (11%). Tubes were applied more commonly (55.6%), compared to bifurcated grafts (44.4%). In terms of postoperative outcomes, intensive care unit (ICU) stay was 1.2 (0.3–32) days, and hospitalization lasted 6.7 (3–39) days with a mean follow-up of 46 months.

Laparoscopic-assisted surgery of AAA: From 1997 to 2002, 172 patients, with a mean age of 69.7 (53–87) years, were treated with the retroperitoneal approach.^{9–11} Mean operative time was 266 (90–690) minutes, clamping time was 96 (30–286) minutes, intraoperative blood loss was 981.4 mL, and conversion was required in 5 (2.9%) patients. Ninety-two (53.5%) tubes and 53 (30.8) aortoiliac and 27 (15.7) aortofemoral grafts were placed. The total patency rate was 95%. The average hospital stay was 4.7 days, with 1.2% of the patients requiring reintervention.

Hand-assisted laparoscopy of AAA: From 1996 to 2008, 453 patients, with a mean age of 67.4 years and mean aneurysm size of 5.6 cm, were treated with the hand-assisted laparoscopic approach.^{6,12,13} The average duration of the procedure was 220 (SD = 58.7) minutes. Mean intraoperative blood loss was 901.7 mL. For anatomical repair, 66.2% of the patients received tubes, 33.3% aortoiliac and 0.5%

Table 109.1 Demographics

Trial identification	Country	Study period	Number of patients	Male	Female	Mean age (range), years	Mean aneurysm size (range), cm
<i>Total laparoscopic surgery of AAA</i>							
Kolvenbach et al. ⁶	Germany	2000–2005	131	N/A	N/A	N/A	N/A
Cochennec et al. ⁷	France	July 2003–December 2004	30	28	2	73.5 (46–85)	5.39 (4.3–9.7)
Javerliat et al. ⁸	France	February 2002–August 2010	99	N/A	N/A	68 (53–79)	5.1 (4.5–6.9)
<i>Laparoscopic-assisted surgery of AAA</i>							
Castronuovo et al. ⁹	United States	February 1997–May 1999	60	51	9	70.6 (53–87)	5.7 (4.4–8.0)
de Donato et al. ¹⁰	Italy	November 1999–December 2002	80	69	11	69 (56–83)	N/A
Cardon et al. ¹¹	France	March 2001–September 2001	32	N/A	N/A	N/A	N/A
<i>Hand-assisted laparoscopy of AAA</i>							
Kolvenbach et al. ⁶	Germany	1996–2000	215	N/A	N/A	N/A	N/A
Ferrari et al. ¹²	Italy	October 2000–October 2008	188	182	6	69 (N/A)	5.5 (N/A)
Veroux et al. ¹³	Italy	May 2006–May 2008	50	50	0	61.2 (N/A)	5.9 (SD = 1.8)
<i>Total laparoscopic surgery of JAAA</i>							
Di Centa et al. ¹⁴	France	February 2002–December 2007	32	29	3	70 ^M (50–84)	5.5 ^M (4.0–9.5)
<i>Laparoscopic-assisted surgery of JAAA</i>							
Ferrari et al. ¹²	Italy	October 2000–October 2008	83	81	2	71 (N/A)	5.7 (N/A)
<i>Total laparoscopic surgery of AIOD</i>							
Dion et al. ¹⁵	Canada	March 1997–June 2003	49	N/A	N/A	56.6 (37–75)	N/A
Kolvenbach et al. ⁶	Germany	2000–2005	105	N/A	N/A	N/A	N/A
Cau et al. ¹⁶	France	September 2002–April 2005	72	63	9	60 (42–83)	N/A
Di Centa et al. ¹⁷	France	November 2000–December 2005	150	138	12	60 (36–83)	N/A
<i>Hand-assisted laparoscopy of AIOD</i>							
Klem et al. ¹⁸	The Netherlands	January 1999–December 2002	33	23	10	59 (39–85)	N/A
<i>Laparoscopic-assisted surgery of AIOD</i>							
Kolvenbach et al. ⁶	Germany	1996–2000	187	N/A	N/A	N/A	N/A

Abbreviations: AAA, abdominal aortic aneurysm; AIOD, aortoiliac occlusive disease; JAAA, juxtarenal abdominal aortic aneurysm; M, median; N/A, not available; SD, standard deviation.

aortofemoral grafts. Patients were hospitalized for approximately 4.2 days, and mean follow-up lasted for 32 months.

Laparoscopic surgery of juxtarenal AAA (JAAA): Two studies conducted between 2000 and 2008 reported data on total laparoscopic and laparoscopic-assisted surgery for JAAA.^{6,14}

A total of 115 patients were included in these studies, and 40% of those had ASA status I–II and 60% ASA status III–IV. Conversion occurred in 2 (1.7%) of the cases, and vascular reconstruction entailed implementation of 74 (64.4%) tubes, 30 (26%) aortoiliac and 11 (9.6%) aortofemoral grafts. Postoperatively, patients stayed in the ICU for 1 day and in department wards for 5.8 days. Mean follow-up was 34.9 months; four patients were lost during this period.

Laparoscopic treatment of AIOD: In less than a decade (1996–2005), 596 patients were treated laparoscopically for AIOD.^{6,15–18} Median operative time was 214 (100–420) minutes, median clamping time was 51 (15–190) minutes, and median intraoperative blood loss was 491 (100–6500) mL. Approximately 5.1% of the procedures required extension of the incision for more than 10 cm. Patients remained in

the ICU for 0–39 days, and hospitalization ranged between 2 and 90 days.

Total laparoscopic surgery for AIOD: Four major studies were published during 1997–2005, enlisting 376 patients with a mean age of 59.4 (36–83) years.^{6,15–17} In terms of Fontaine classification, 72.4% of the participants were stage II, 15.8% were stage III, and 11% were stage IV. Similarly for TASC stages, 6.3% of the cases were stage B, 53.1% stage C, and 32.5% stage D. Finally, patient characterization per ASA status was as follows: I: 1.1%, II: 49.1%, III: 44.9%, and IV: 4.9%. Moreover, median operative time was 233 (120–450) minutes, median clamping time was 66 (25–190) minutes, and median intraoperative blood loss was 479 (100–3900) mL. Conversion was inevitable in 24 (6.3%) patients. In addition, 313 (84%) bifemoral and 61 (16%) unifemoral grafts were applied achieving a total patency of 95.4%. Postoperative patients were in the ICU for 1 (0–5) day and in the department wards for another 7.3 (2–90) days. Indeed, 4.5% of the subjects required reintervention in

Table 109.2 Comorbidities and preoperative clinical data

Trial identification	Coronary disease (%)	Dyslipidemia (%)	Arterial hypertension (%)	Diabetes mellitus (%)	Smoking (%)	COPD (%)	CRD (%)	Previous surgery (%)
<i>Total laparoscopic surgery of AAA</i>								
Kolvenbach et al. ⁶	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cochennec et al. ⁷	N/A	17 (56.6)	17 (56.6)	4 (13.3)	23 (76.6)	N/A	N/A	3 (10)
Javerliat et al. ⁸	20 (20.2)	57 (57.5)	53 (53.5)	10 (10.1)	85 (85.8)	N/A	N/A	N/A
<i>Laparoscopic-assisted surgery of AAA</i>								
Castronuovo et al. ⁹	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
de Donato et al. ¹⁰	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cardon et al. ¹¹	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
<i>Hand-assisted laparoscopy of AAA</i>								
Kolvenbach et al. ⁶	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ferrari et al. ¹²	50 (26.6)	42 (22.3)	97 (51.6)	11 (5.8)	N/A	58 (30.8)	16 (8.5)	N/A
Veroux et al. ¹³	15 (30)	24 (48)	48 (96)	33 (66)	38 (76)	17 (34)	N/A	N/A
<i>Total laparoscopic surgery of JAAA</i>								
Di Centa et al. ¹⁴	5 (15.6)	N/A	18 (56.2)	5 (15.6)	N/A	2 (6.2)	9 (28.1)	15 (46.8)
<i>Laparoscopic-assisted surgery of JAAA</i>								
Ferrari et al. ¹²	31 (37.3)	21 (25.3)	58 (69.9)	4 (4.8)	N/A	23 (27.7)	14 (16.9)	N/A
<i>Total laparoscopic surgery of AIOD</i>								
Dion et al. ¹⁵	17 (34.7)	40 (81.6)	27 (55.1)	6 (12.2)	44 (89.8)	5 (10.2)	2 (4.1)	N/A
Kolvenbach et al. ⁶	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Cau et al. ¹⁶	23 (32)	16 (22)	37 (51)	19 (26)	60 (83)	14 (19)	N/A	14 (19.4)
Di Centa et al. ¹⁷	N/A	46 (30.7)	73 (48.7)	29 (19.3)	145 (96.7)	N/A	N/A	58 (38.7)
<i>Hand-assisted laparoscopy of AIOD</i>								
Klem et al. ¹⁸	6 (18)	4 (12)	9 (27)	7 (21)	21 (63.6)	1 (3)	N/A	N/A
<i>Laparoscopic-assisted surgery of AIOD</i>								
Kolvenbach et al. ⁶	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Abbreviations: AAA, abdominal aortic aneurysm; AIOD, aortoiliac occlusive disease; COPD, chronic obstructive pulmonary disease; CRD, chronic renal disease; JAAA, juxtarenal abdominal aortic aneurysm; N/A, not available.

the immediate postoperative period. Mean follow-up was 24 (1–77) months.

Laparoscopy-assisted and hand-assisted laparoscopy for AIOD: In the period of 1996–2002, 220 patients were operated on with either one of these techniques.^{6,18} The procedures lasted for a median of 182 (100–420) minutes with the median clamping time being 26 (15–90) minutes. Moreover, 513 (150–6500) mL of blood was lost during surgery with a conversion dynamic of 7 (3%) cases. Median ICU support was 0.95 (0–39) days with a total hospitalization of 6.4 (4–53) days.

MORBIDITY

The most common postoperative complication was transient renal insufficiency (TRI). The highest incidence was noted with laparoscopic repair of JAAs in 17 (14.7%) cases, followed by 18 (6.8%) reports in the total laparoscopic repair of AAAs, 3 (1.75%) in the laparoscopic-assisted group, and 4 (0.84%) in the hand-assisted laparoscopy. The

total laparoscopic repair group for AIOD had 10 (2.7%) patients with TRI. Other complications included postoperative bleeding, peripheral ischemia, pneumonia, adult respiratory distress syndrome, retroperitoneal hematoma, nonlethal myocardial infarction, arrhythmias, ischemic colitis, deep venous thrombosis, ileus, sexual dysfunction, graft thrombosis, superficial infections, and incisional hernias.

MORTALITY

Thirty-day mortality for the total laparoscopic technique was 1.9% ($n = 5$), in contrast to 1.8% ($n = 4$), 1.1% ($n = 7$), and 0.8% ($n = 1$) in the laparoscopy-assisted procedure for AAA, hand-assisted laparoscopy group for AAA, and laparoscopic approaches for JAAA, respectively. Similarly, 30-day mortality was 1.9% ($n = 7$) in the total laparoscopic repair of AIOD and 1.4% ($n = 3$) in the combined group of laparoscopy-assisted and hand-assisted laparoscopy for AIOD. Undoubtedly, the majority of deaths were attributed

Table 109.3 Operative data

Trial identification	Approach	Mean operative time (range), minutes	Mean clamping time (range), minutes	Clamp location	Mean operative blood loss (dispersion measure), mL	Conversion to open surgery, n (%)
<i>Total laparoscopic surgery of AAA</i>						
Kolvenbach et al. ⁶	TPRC/TPRR	265 ^M (145–405)	95 ^M (30–160)	N/A	1100 (250–3000)	23 (17.6)
Cochennec et al. ⁷	TPRR/RP/TPD	255 (170–410)	80 (35–110)	Infrarenal/suprarenal 29/1	1600 (400–4000)	1 (3.3)
Javerliat et al. ⁸	N/A	210 (180–520)	81 (35–140)	Infrarenal/suprarenal 96/3	N/A	5 (5)
<i>Laparoscopic-assisted surgery of AAA</i>						
Castronuovo et al. ⁹	RP	462 (90–690)	112 (43–286)	N/A	1490 (N/A)	3 (5)
de Donato et al. ¹⁰	RP	167 (SD = 18)	N/A	N/A	600 (300–1000)	0
Cardon et al. ¹¹	RP	148 (90–260)	66 (30–135)	N/A	N/A	2 (6)
<i>Hand-assisted laparoscopy of AAA</i>						
Kolvenbach et al. ⁶	TPRC/TPRR	175 ^M (85–290)	55 ^M (25–130)	N/A	850 (150–1800)	11 (5.1)
Ferrari et al. ¹²	N/A	231 (SD = 64)	25 (SD = 5)	Infrarenal	961 (SD = 633)	0
Veroux et al. ¹³	N/A	178 (SD = 39)	N/A	N/A	N/A	N/A
<i>Total laparoscopic surgery of JAAA</i>						
Di Centa et al. ¹⁴	TPRC/TPRR 8/24	270 ^M (215–410)	83 ^M (36–147)	Suprarenal/infrarenal 14/18	850 ^M (215–2400)	2 (6)
<i>Laparoscopic-assisted surgery of JAAA</i>						
Ferrari et al. ¹²	N/A	220 (SD = 66)	28 (SD = 6)	Suprarenal	1023 (SD = 584)	0 (0)
<i>Total laparoscopic surgery of AIOD</i>						
Dion et al. ¹⁵	TRP	AIOD: 290 (SD = 62) IOD: 193 (SD = 58)	AIOD: 99 (SD = 28) IOD: 100 (SD = 40)	Infrarenal	AIOD = 497 (SD = 329), IOD = 267 (SD = 153)	5 (10.2)
Kolvenbach et al. ⁶	TPRC/TPRR	195 ^M (125–250)	45 ^M (25–115)	N/A	450 ^M (100–2000)	12 (11.4)
Cau et al. ¹⁶	TPRC	216 (SD = 50)	57 (SD = 21)	Infrarenal/suprarenal 69/3	450 (150–2250)	2 (2.7)
Di Centa et al. ¹⁷	TPRC (86), TPRR (51), TPD (4), RP (9)	260 ^M (120–450)	81 ^M (36–190)	Infrarenal/suprarenal N/A	500 ^M (100–3900)	5 (3.3)
<i>Hand-assisted laparoscopy of AIOD</i>						
Klem et al. ¹⁸	TPD: 22, RP: 7, apron: 4	TP: 240 ^M (185–390) RP: 420 ^M (380–420) Apron: 263 ^M (227–270)	TP: 32.5 ^M (15–67), RP: 40 ^M (25–90), Apron: 33.5 ^M (22–45)	Infrarenal	TP: 1150 ^M (150–6500), RP: 2100 ^M (1200–4000), Apron: 950 ^M (400–1500)	3 (9)
<i>Laparoscopic-assisted surgery of AIOD</i>						
Kolvenbach et al. ⁶	TPRC/TPRR	165 ^M (100–250)	25 ^M (15–40)	N/A	370 ^M (250–1200)	4 (2)

Abbreviations: AAA, abdominal aortic aneurysm; AIOD, aortoiliac occlusive disease; JAAA, juxtarenal abdominal aortic aneurysm; M, median; N/A, not available; RP, retroperitoneal; SD, standard deviation; TPD, transperitoneal direct; TPRC, transperitoneal retrocolic; TPRR, transperitoneal retrorenal; TRP, transabdominal retroperitoneal.

Table 109.4 Tubes and grafts

Trial identification	Tube (%)	Aortoiliac graft (%)	Aortofemoral graft (%)	Bifemoral graft (%)	Unifemoral graft (%)	Graft patency (%)
<i>Total laparoscopic surgery of AAA</i>						
Kolvenbach et al. ⁶	72 (55)	59 (45)	0	0	0	N/A
Cochennec et al. ⁷	13 (43.3)	17 (56.7)		0	0	N/A
Javerliat et al. ⁸	60 (60)	39 (40)		0	0	N/A
<i>Laparoscopic-assisted surgery of AAA</i>						
Castronuovo et al. ⁹	1 (1.7)	39 (65)	20 (33.3)	0	0	95
de Donato et al. ¹⁰	70 (87.5)	10 (12.5)	0	0	0	100
Cardon et al. ¹¹	21 (65.6)	4 (12.5)	7 (21.9)	0	0	N/A
<i>Hand-assisted laparoscopy of AAA</i>						
Kolvenbach et al. ⁶	128 (59.5)	87 (40.5)	0 (0)	0	0	N/A
Ferrari et al. ¹²	139 (73.9)	47 (25)	2 (1.1)	0	0	98.4
Veroux et al. ¹³	N/A	N/A	N/A	0	0	N/A
<i>Total laparoscopic surgery of JAAA</i>						
Di Centa et al. ¹⁴	16 (50)	8 (25)	8 (25)	0	0	N/A
<i>Laparoscopic-assisted surgery of JAAA</i>						
Ferrari et al. ¹²	58 (69.9)	22 (26.5)	3 (3.6)	0	0	98.8
<i>Total laparoscopic surgery of AIOD</i>						
Dion et al. ¹⁵	0	0	0	46 (93.8)	3 (6.2)	96.1
Kolvenbach et al. ⁶	0	0	0	90 (85.7)	15 (14.2)	N/A
Cau et al. ¹⁶	0	0	0	66 (91.6)	4 (5.5)	100
Di Centa et al. ¹⁷	0	0	0	111 (74)	39 (26)	93
<i>Hand-assisted laparoscopy of AIOD</i>						
Klem et al. ¹⁸	0	0	0	N/A	N/A	N/A
<i>Laparoscopic-assisted surgery of AIOD</i>						
Kolvenbach et al. ⁶	0	0	0	164 (87.7)	23 (12.2)	N/A

Abbreviations: AAA, abdominal aortic aneurysm; AIOD, aortoiliac occlusive disease; JAAA, juxtarenal abdominal aortic aneurysm; N/A, not available.

to myocardial infarctions ($n = 10$). Less common causes of death were sepsis, multiorgan failure, arrhythmias, acute renal failure, adult respiratory distress syndrome, ischemic colitis, stroke, and peripheral ischemia.

CONCLUDING REMARKS

Laparoscopic treatment of AAAs and AIOD is compatible with less than 5% mortality independent of the approach, has high graft patency, and has acceptable conversion to open surgery risk. Every approach was linked with a less than 3.6% probability of incision extension greater than 10 cm, except total laparoscopic surgery for AAA (11%) and for AIOD (6.3%). Moreover, for all laparoscopic techniques, approximate ICU and hospitalization stays were 1 day and under 7 days, respectively.

Major drawbacks of laparoscopic aortic surgery include the prolonged operation (229 minutes for AAA, 214 minutes

for AIOD) and clamping time (86.8 minutes for AAA, 51 minutes for AIOD). Kolvenbach et al.⁶ estimated the learning curve for the procedure at 20 cases, yet this varies depending on the surgeon's background with laparoscopy and the health-care setting in which these procedures were performed. Notably, even for a well-trained surgeon, the average time to complete the operation laparoscopically raises up to 30%–50%.¹⁹ Hand-assisted laparoscopic surgery is characterized by a relatively shorter operative (and clamping) time, since the technically demanding anastomosis is performed by hand. Also, it requires less ICU and hospital stays, while diminishing morbidity and mortality.^{6,12,13}

To summarize, papers from the last 20 years of laparoscopic aortic surgery are consistent with encouraging outcomes. Vascular Surgery Fellowship programs should aim at offering adequate training in this upcoming field. However, extensive research needs to be conducted in order to safely determine midterm and long-term results

Table 109.5 Outcomes

Trial identification	Mean ICU stay (range), days	Mean hospital stay (range), days	30-day mortality (%)	Early reoperation (%)	Late reoperation (%)	Follow-up (months)	Patients lost at follow-up
<i>Total laparoscopic surgery of AAA</i>							
Kolvenbach et al. ⁶	2 ^M (1–16)	5 ^M (3–21)	4 (3)	N/A	N/A	N/A	N/A
Cochennec et al. ⁷	2 (0.3–18)	9 (5–37)	1 (3.3)	2 (2.2)	N/A	60	1
Javerliat et al. ⁸	1 (0.5–32)	6 (4–39)	0	0	2 (2)	42 (1–97)	6
<i>Laparoscopic-assisted surgery of AAA</i>							
Castronuovo et al. ⁹	2.4 (1–25)	6.3 (1–25)	3 (5)	1 (1.7)	N/A	N/A	N/A
de Donato et al. ¹⁰	0	3.5 (N/A)	2 (2.5)	0	N/A	18 (4–37)	4
Cardon et al. ¹¹	N/A	N/A	1 (3.1)	1 (3.1)	0	N/A	N/A
<i>Hand-assisted laparoscopy of AAA</i>							
Kolvenbach et al. ⁶	2 ^M (0–8)	7 ^M (5–18)	4 (1.8)	N/A	N/A	N/A	N/A
Ferrari et al. ¹²	0.6 (SD = 1.04)	4.2 (SD = 1.9)	0	N/A	N/A	37.9 (SD = 20)	3
Veroux et al. ¹³	N/A	4.2 (N/A)	0 (0)	1 (2)	3 (6)	12	0
<i>Total laparoscopic surgery of JAAA</i>							
Di Centa et al. ¹⁴	2 (0.5–23)	10 (4–37)	1 (3.1)	N/A	N/A	27 (1–50)	3
<i>Laparoscopic-assisted surgery of JAAA</i>							
Ferrari et al. ¹²	0.6 (SD = 0.7)	4.2 (SD = 1.5)	0	0	1 (1.2)	37.9 (SD = 20)	1
<i>Total laparoscopic surgery of AIOD</i>							
Dion et al. ¹⁵	AIOD: 0.9 IOD: 0	AIOD: 5 ^M (SD = 3.6) IOD: 3.3 ^M (SD = 0.6)	1 (2)	1 (2)	3 (6.1)	31.6 (3–77)	3
Kolvenbach et al. ⁶	1 ^M (0–5)	4 ^M (3–22)	2 (1.9)	N/A	N/A	N/A	N/A
Cau et al. ¹⁶	1 (1–2)	8 (5–42)	0 (0)	3 (4.1)	2 (2.7)	17 (1–31)	N/A
Di Centa et al. ¹⁷	N/A	7 (2–90)	4 (2.7)	8 (5.3)	6 (4)	25.2 (SD = 17.6)	19
<i>Hand-assisted laparoscopy of AIOD</i>							
Klem et al. ¹⁸	TP: 0.5 ^M (0.5–1.5), RP: 1 ^M (0.5–39), Apron: 0.75 ^M (0.5–1)	TP: 8 ^M (5–18), RP: 12.5 ^M (4–53), Apron: 7 ^M (6–7)	0	N/A	N/A	N/A	N/A
<i>Laparoscopic-assisted surgery of AIOD</i>							
Kolvenbach et al. ⁶	1 ^M (0–9)	6 ^M (4–17)	3 ^M (1.6)	N/A	N/A	N/A	N/A

Abbreviations: AAA, abdominal aortic aneurysm; AIOD, aortoiliac occlusive disease; JAAA, juxtarenal abdominal aortic aneurysm; M, median; N/A, not available; SD, standard deviation.

of laparoscopically treated AAAs and AIOD, especially in comparison to EVAR and open surgery.

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Laparoscopic median arcuate ligament release

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INTRODUCTION

Median arcuate ligament syndrome (MALS) is a rare condition known by several names, including celiac artery compression syndrome, celiac axis syndrome, celiac trunk compression syndrome, Dunbar syndrome, Harjola-Marable syndrome, and Marable syndrome. Harjola is credited with the first description of this syndrome in 1963.¹ Typically the syndrome is postprandial pain with weight loss and external compression of the celiac artery by the arcuate ligament. The etiology is unknown.

PATHOPHYSIOLOGY

The pathophysiology is controversial, and two main theories prevail. Some have suggested that mechanical compression of the celiac artery by the median arcuate ligament leads to mesenteric ischemia.^{1,2} Others believe in a neurogenic process involving compression of the celiac plexus causing either pain from sympathetic chain irritation or nerve compression leading to splanchnic vasoconstriction and concomitant ischemia.²⁻⁴ Treatment is aimed at releasing the median arcuate ligament at the level of the celiac axis and includes dissection of any neural fibers around the celiac axis.⁴ This allows for mechanical release of the celiac artery as well as relief of stimulation from the nerves.⁵ Treatment may also involve subsequent endovascular intervention if there is continued celiac artery stenosis after initial surgical decompression.⁶

EPIDEMIOLOGY

The incidence of celiac artery compression is 10%–24%, but only about 1% of the patients are symptomatic.⁷ The disease affects all groups, but there is a 3:1 female-to-male

ratio, and the peak age group is 20–40 years. Commonly, patients are thin, and there is a prevalence in the Asian population.^{5,7-10} MALS is a diagnosis of exclusion, and symptoms are similar to a host of other disease states such as gallbladder disease, appendicitis, mesenteric ischemia, gluten intolerance, and irritable bowel disease. In order to rule out other gastrointestinal pathology, patients require a significant workup prior to diagnosis of MALS.¹¹

HISTORY AND PHYSICAL EXAM

MALS classically presents as a triad: postprandial abdominal pain, weight loss, and epigastric bruit.¹¹ The triad is not present in all cases, and symptoms are variable and can often include nausea, vomiting,¹² diarrhea, positional changes in pain, and pain that may not be associated with meals. Physical exam of a patient with MALS can be benign, and often no abdominal pain is noted on palpation. The bruit is classically increased with inspiration, which further compresses the celiac artery with the arcuate ligament.

ANATOMY

The median arcuate ligament is formed at the base of the diaphragm at the confluence of the right and left crura at approximately the 12th thoracic vertebrae (**Figure 110.1**). The crura are attached to the anterior surface of L1 to L4 on the right and from L2 to L3 on the left. The connection of these crura form a musculofibrous arch creating the anterior aspect of the aortic hiatus, where the aorta, thoracic duct, and azygos vein travel. The celiac axis typically comes off of the aorta distal to this hiatus. However, in patients with MALS, the ligament is found to have a low insertion or the artery a high origin, which can cause compression of the artery or the celiac ganglion or both.

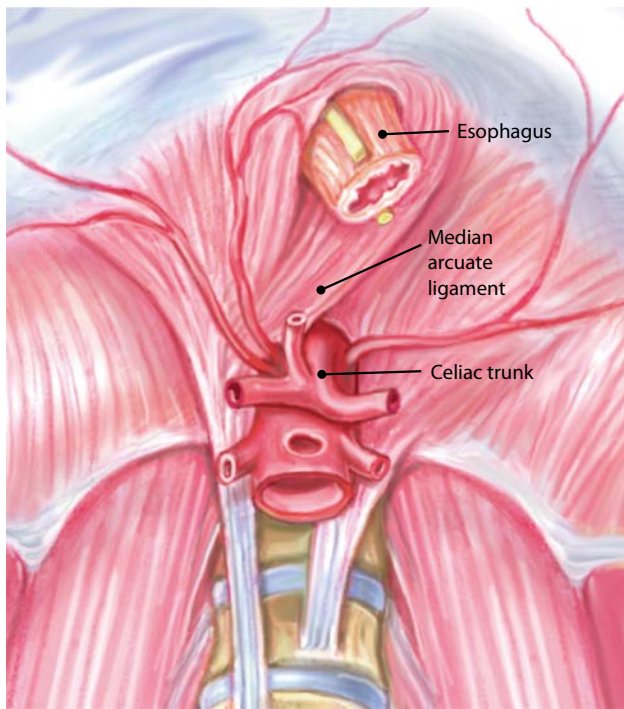


Figure 110.1 Median arcuate ligament.

DIAGNOSIS AND TREATMENT

The diagnosis of MALS is made first on the basis of symptomatology with supportive radiologic findings. Since MALS is a diagnosis of exclusion, patients should be worked up for medical illnesses that can cause upper abdominal pain. Therefore, workup should include blood labs, computed tomography (CT) scan, ultrasound, and endoscopy.

The diagnosis hinges on demonstration of celiac artery compression. Traditionally this was tested using conventional angiography, but currently this modality is used rarely for initial evaluation because of the potential risks of this procedure.⁷ Patients now undergo duplex ultrasound or CT scan. Duplex ultrasounds will show increased velocities, especially in the expiratory phase. Peak systolic velocities greater than 200 cm/s and end diastolic velocities greater than 55 cm/s in the celiac artery are considered diagnostic (**Figures 110.2 and 110.3**). Retrograde flow into the hepatic artery is considered to be 100% predictive of severe celiac stenosis or occlusion.^{5,6,13} Diagnosis or confirmation of diagnosis can be made with an abdominal CT scan with or without three-dimensional reconstruction showing stenosis and a characteristic hook appearance of the celiac axis (**Figures 110.4 and 110.5**). Magnetic resonance angiography of the celiac axis has also been used for diagnosis.

Once a diagnosis of MALS has been made, the treatment is release of compression on the celiac axis by surgically cutting the ligament along with fibrous bands and ganglionic tissues. This may include a celiac ganglion sympathectomy,⁵ which has historically been done through a laparotomy, but the laparoscopic approach is preferred.

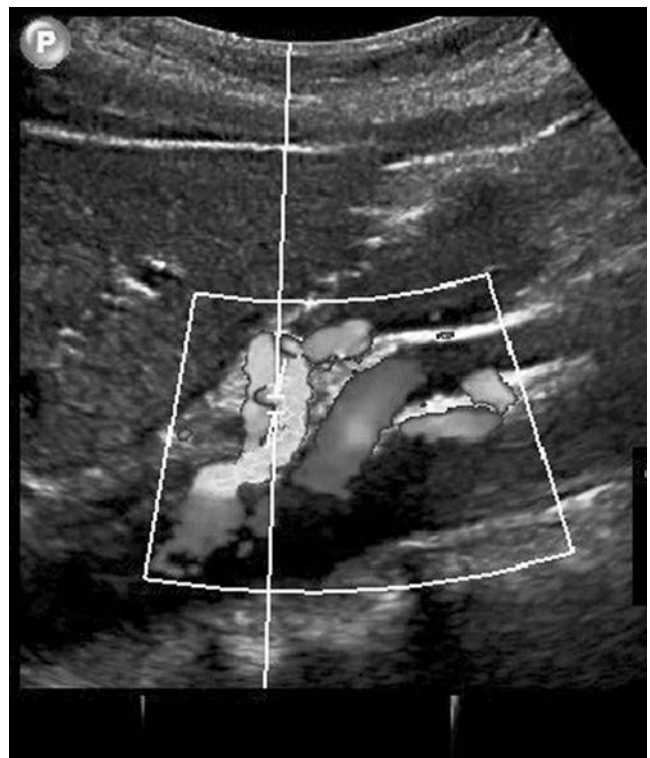


Figure 110.2 Mesenteric ultrasound of the celiac artery. (Republished with permission of Lainez RA, Richardson WS. *Ochsner J.* 2013;13(4):561–4.²³)

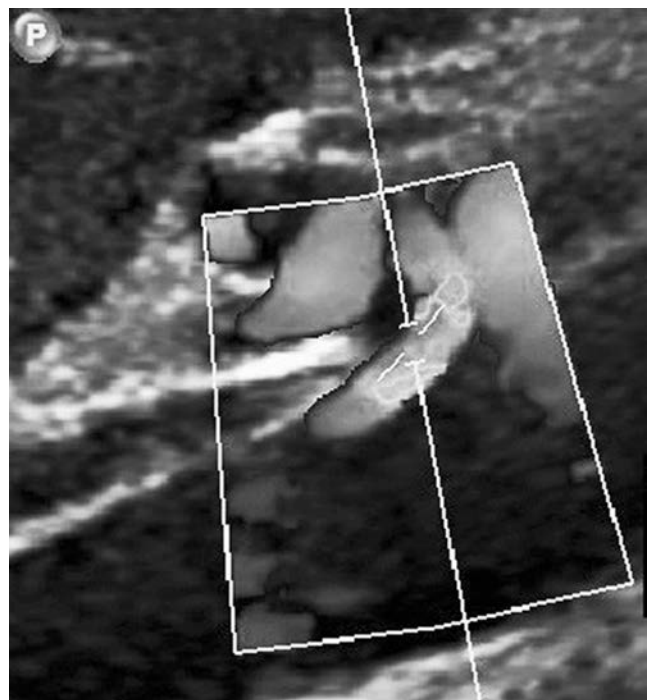


Figure 110.3 Ultrasound velocities were augmented to >300 cm/s upon inspiration. (Republished with permission of Lainez RA, Richardson WS. *Ochsner J.* 2013;13(4):561–4.²³)

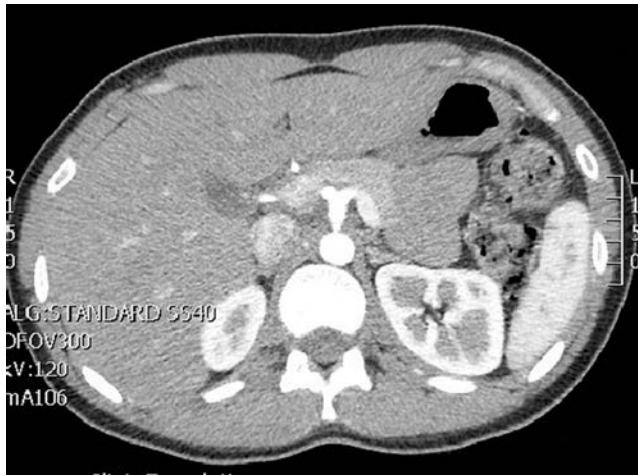


Figure 110.4 Computed tomography angiography showing stenosis of the celiac artery without any evidence of atherosclerosis. (Republished with permission of Lainez RA, Richardson WS. *Ochsner J.* 2013;13(4):561–4.²³)

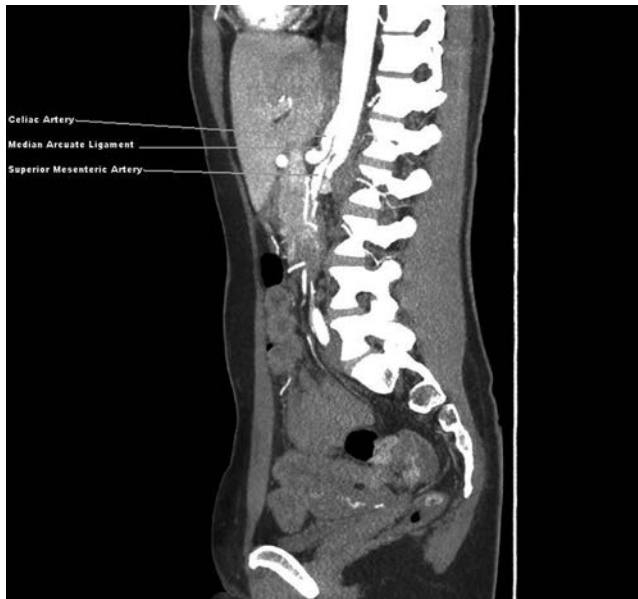


Figure 110.5 Sagittal view of the computed tomography angiography showing compression of the celiac artery. (Republished with permission of Lainez RA, Richardson WS. *Ochsner J.* 2013;13(4):561–4.²³)

PROCEDURE

The patient is placed under general anesthesia on a straight split-leg table in the supine position with the arms extended and the legs abducted.¹² One monitor is placed over the head and one over the right shoulder. A Mayo tray is placed over the left leg, and the scrub tech and table are to the foot of the bed, behind the surgeon, who works from between the legs. The assistant sits on the patient's left, and an optional

second assistant can be used on the patient's right for camera holding. Access to the peritoneum is gained 15 cm or less below the xiphoid and just to the left of midline with a 10 mm trocar. Pneumoperitoneum to 15 mm with CO₂ gas is attained, and the patient is placed in steep reverse Trendelenburg. More cephalad can be helpful as it can be hard to see into the angle between the celiac and aorta. Then 4 × 5 mm trocars are placed subcostally at 11 cm and as far laterally as is safe on the left side, and 7 and 15 cm on the right from the xiphoid. The right lateral trocar is used for the liver retractor, which is used to expose the esophageal hiatus and is secured to the bed. Using an energy source, the lesser sac is entered above and, preserving the vagal branches to the liver and the peritoneum over the esophagus, is divided to facilitate its retraction. The tissues under the esophagus are divided, exposing the area where the crura meet posterior to the esophagus. This dissection is taken down to the left gastric vessel, and if necessary, the vagal branches to the liver are taken to aid exposing this area. Using the hook cautery, the crura are divided at the hiatus exposing the anterior aorta. With blunt graspers in the operator's left hand and through the assistant port, the esophagus is reflected to the patient's left passively by the assistant's grasper and the crura are retracted to either side of the aorta. The hook cautery is used to expose the anterior aorta caudad onto the celiac trunk and to the branches of the celiac artery. Crural attachments and lymphatic and neural tissue are divided to expose the vessels. The laparoscopic ultrasound is used liberally to determine the anatomy and identify structures. Frequently, confirmation of release of the celiac stenosis can be seen with the ultrasound. The abdomen is inspected for hemostasis, and the trocars are removed.

OUTCOMES

More recently, surgeons have moved away from open surgery and toward laparoscopic and robotic approaches with similar outcomes.^{7,11,12} The first laparoscopic and robotic procedures were described in 2000 and 2007, respectively. Direct comparisons of both approaches have shown similar outcomes.^{12,14–16} The robotic approach is beyond the scope of this chapter.

Patients who improve the best from a median arcuate release are those aged 40 to 60 who lack a psychiatric condition or alcohol use, have worsening pain after meals, and have weight loss greater than 20 pounds (9.1 kg).^{17,18} It has been noted that patients who present with atypical pain, no weight loss, and intermittent use of narcotics are less likely to benefit from surgical intervention.^{2,19}

After laparoscopic release, the majority of patients have symptomatic improvement (**Table 110.1**).^{6,12,14,20–22} The better outcomes are in patients with typical symptoms and in the typical age group as previously described. Operating room time varies but is typically under 2 hours. Most conversions were due to intraoperative bleeding. This suggests that care with dissection is very important. There were many types of

Table 110.1 Outcomes of MAL release

Symptom improvement	66%–90%
Surgery time	101–189 minutes
Conversion	0%–0.18%
Further procedures	0.18%–64%

further procedures: rerelease, stenting, and reimplantation. The vast majority of these patients had continued stenosis on imaging after laparoscopic release and improved with these procedures. We believe that this is due to vessels that do not dilate despite adequate ligament release rather than incomplete ligament release.

CONCLUSION

The majority of well-selected patients will benefit from median arcuate ligament release. The most encountered major complication is bleeding. Although minimally invasive ligament release is the best first procedure, a significant number of patients will require further procedures.

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Minimally invasive approach to retroperitoneal collections in necrotizing pancreatitis

PIETER TIMMERMAN, MARC G.H. BESSELINK, AND KAREN D. HORVATH

INDICATIONS

Approximately 20% of patients with acute pancreatitis develop necrotizing pancreatitis.¹ Retroperitoneal collections in necrotizing pancreatitis most frequently consist of a combination of pancreatic parenchymal and/or peripancreatic fat necrosis with fluid. In 30% of the cases, secondary infection of the retroperitoneal collections occurs. Infected necrosis is associated with a mortality rate of 12%–29%,^{1–4} and is virtually always an indication for surgical intervention.⁵

In order to minimize postoperative morbidity, it is advised to postpone operative intervention until 4 weeks after the start of the first symptoms of the disease. During these first weeks of the disease, one should attempt to stabilize the condition of the patient, begin nutritional supplementation, and focus on intensive care treatment in the case of organ failure. In the case of suspected infection, the patient may require antibiotics with or without placement of percutaneous drains. During this 4-week period, the necrotic collections mature and become encapsulated, now referred to in the revised Atlanta classification as “walled-off pancreatic necrosis” (WOPN).⁶ Delaying operative intervention to occur in the stage of WOPN is considered to reduce the risk of intraoperative and postoperative complications, in particular, bleeding.

When infection is suspected, a computed tomography (CT) scan should be done. In 50% of patients with proven infected necrosis, these scans depict gas bubbles in the necrotic collection. In the absence of gas bubbles, a fine-needle aspiration (FNA) may help to further clarify the diagnosis of infection. However, with false-negative results of up to 25%, a negative FNA culture or lack of gas bubbles on CT scan does not rule out infection. Often, the diagnosis can be made with high reliability simply based on strong clinical suspicion of infected necrosis.⁷ Sterile collections in

necrotizing pancreatitis uncommonly require intervention and will not be discussed here.

Once infected necrosis is suspected, antibiotics should be started. A limited group (approximately 5%) of patients with infected necrotizing pancreatitis can be treated with antibiotics alone. If patients deteriorate or *fail to consistently progress using clear objective criteria* under antibiotic treatment, invasive intervention is indicated. Since the randomized, controlled PANTER trial report,⁸ the Step-up Approach is considered a standard approach to infected WOPN with Level I evidence. The first step consists of percutaneous catheter drainage. Approximately 35% of patients will recover with only catheter drainage. The remaining patients will need to undergo minimally invasive surgical necrosectomy. Several strategies have been described, including transgastric endoscopic approaches, with the best approach for each patient being highly customized. In this chapter we discuss video-assisted retroperitoneal debridement (VARD). VARD is a relatively simple, low-cost, and low-tech procedure requiring few resources, and no fluoroscopy. It is a highly effective approach that can easily be subdivided into teachable steps.

PREOPERATIVE PREPARATION

A high-quality contrast-enhanced CT scan with coronal reconstructions is important to determine the extensions of the WOPN collection(s) and how these are best accessed via percutaneous catheter drainage. It is important to see if there is left (or right) paracolic extension of the infected collection over Gerota’s fascia. In 95% of patients, catheter drainage is feasible, mostly via the retroperitoneal route as is required for VARD. Rarely a transabdominal catheter



Figure 111.1 CT scan of patient with infected WOPN showing a percutaneous drain, placed via a left subcostal approach over Gerota's fascia.

drain or an endoscopic transgastric/duodenal drainage is required. In these instances VARD is not recommended.

A well-positioned catheter through the left retroperitoneum deep into the infected collection is important in order to perform the VARD procedure safely. Typically, the drain is placed over Gerota's fascia of the left kidney (**Figure 111.1**). The catheter should be flushed with at least 50 mL saline three times a day to promote lavage of the cavity. Clinical

improvement should be noted within 3 days. A new CT scan should be performed about 7 days later and can objectify if the collection decreases in size and whether the drains are in good position. Repositioning or upsizing of the drains even to 24 Fr can be done successfully and necrosectomy avoided. Complete drainage of all necrosis is not required if the patient continues to improve in all parameters. If in 1–2 weeks no significant decrease of the collection has been seen, and/or if the patient deteriorates clinically, the next step is a VARD procedure.

ANESTHESIA

General anesthesia with endotracheal intubation is required. Broad-spectrum antibiotic prophylaxis aimed at intestinal microorganisms is administered.

POSITION

The patient is placed in the supine position on a beanbag with the xiphoid over the flex point of the operating table. The patient's left side is elevated with a roll placed under the left flank, and the left arm is positioned over the patient's head, padded, and fixated (**Figure 111.2**). In order to increase the distance between costal margin and pelvic rim, the operating table is flexed. Before final positioning and draping the patient, the following landmarks are marked: xiphoid, costal margin, anterior superior iliac spine, and midaxillary line, as



Figure 111.2 Patient positioning for VARD procedure. Patient has a roll under left flank.



Figure 111.3 Important landmarks identified prior to draping while patient is still in supine position.

well as the planned incision site (**Figure 111.3**). The 4–5 cm planned incision site is marked one fingerbreadth below the left costal margin over the midaxillary line. Marking before draping is important, since it can be difficult to accurately determine these important landmarks afterward. The abdomen is fully exposed and prepped, as occasionally, laparotomy is required. Once the patient is draped, the table is rolled 20° to the right. This way, the route of the percutaneous drain from the skin to the retroperitoneal cavity is in a horizontal plane. A collection bag placed under the incision is helpful to collect pus and irrigation fluid.

OPERATIVE PREPARATION

The preoperative CT scan should be reviewed and available on a screen in the operating room. Required instruments include 5–10 mm laparoscope (0°), extra-long 10/12 mm port without the trocar, long ring forceps, deep Deaver retractors, liberal amounts of warm saline, pulse-lavage system, and two 1-inch Penrose surgical drains. In the rare case of bleeding, a laparoscopic clip applicator may be helpful.

DETAILS OF PROCEDURE

A 4–5 cm left subcostal incision is made in the midaxillary line. The three abdominal wall muscle layers are divided. Immediately under the transversus muscle, a thin line indicating the junction of the peritoneum with the retroperitoneum becomes visible. With blunt finger dissection in this plane, the drain is located cranially and followed into the collection. The wall of the collection is typically very firm. The drain can be felt entering the WOPN along the horizontal plane (**Figure 111.4**). It is important to stay exactly on the drain in order to avoid entry into the peritoneal space with damage to the colon (positioned anterior),

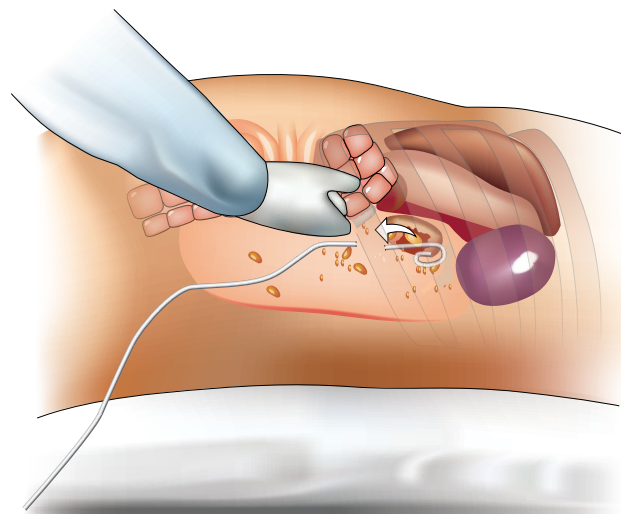


Figure 111.4 Entrance of the finger into the WOPN cavity next to the drain.

the spleen (positioned superior), and the kidney (positioned posterior). Once the drain is felt entering the firm wall of the collection, a straight clamp placed around the drain can also be used for entry. The drainage of pus signals the entering of the collection. A deep Deaver retractor is now placed ventrally through the opening into the collection, thus enabling a clear view of the entrance into the collection.

The first bit of necrosis is removed using blunt dissection with a Yankauer suction and the ring forceps (**Figure 111.5**). Once a cavity becomes visible, the laparoscope is placed directly into the collection through an extra-long port. This long port is helpful to prevent impaired vision due to smudging of the camera. The port is placed at the dorsal edge of the incision (**Figure 111.6**). Optionally, the percutaneous drain can be connected to a CO₂ gas insufflator to help the cavity expand. Large pieces of necrosis can be removed under video assistance directly through the incision without the need for a second port. Necrotic tissue is sent for microbiological assessment.

It is important only to remove loosely adherent necrosis in order to prevent bleeding. Nearby arteries include the splenic artery but also the splenic vein, which may course through the collection. In case of bleeding, a laparoscopic clip applicator may be useful. If clipping of an arterial bleeding is not quickly feasible, the collection should be packed, and the patient transported to interventional radiology for coil embolization. In case of venous bleeding, packing should suffice to stop the bleeding followed by repeat necrosectomy after 24–48 hours. The cavity should be irrigated frequently with pulse lavage, which helps to identify the anatomic structures and necrosis and facilitate hydrodissection of the necrotic tissue. It is not necessary to remove all necrosis, only to substantially reduce the burden.

Once the collection has been cleared of the majority of necrosis and has been irrigated using 2–3 L of pulse lavage, two large Penrose drains are placed deeply into the collection

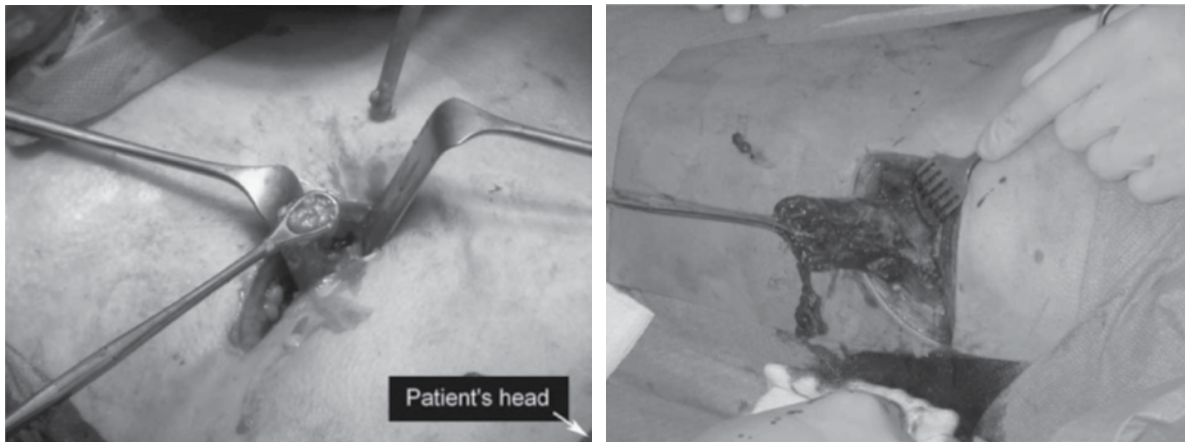


Figure 111.5 Initial dissection done under direct vision with Yankauer suction and ring forceps.

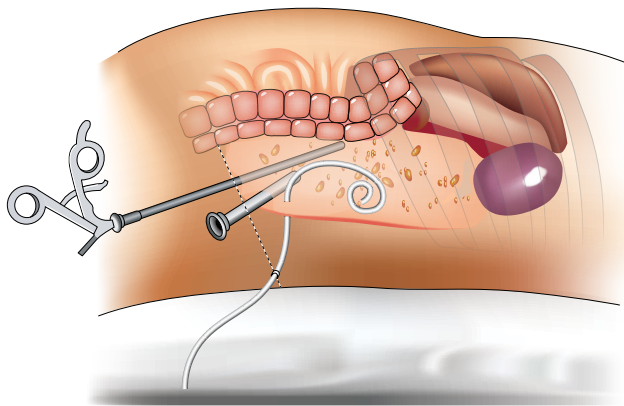


Figure 111.6 Videoscopic-assisted retroperitoneal debridement of infected pancreatic necrosis.

under direction of the laparoscope. One tip is placed at the deepest position and brought out through the dorsal part of the wound or a separate stab incision. The percutaneous drains are left in place. The fascia is closed in three individual layers (transversus, internal oblique, and external oblique abdominis muscles) with individual sutures. Failure to close these layers separately may lead to difficult flank hernias. Drains are sutured to the skin, and the skin may be closed. The Penrose drains are brought into a urostomy appliance and connected to a Foley urimeter for use in the postoperative lavage system ([Figure 111.7](#)). A schematic illustration of the VARD procedure is shown in [Figure 111.8](#).

POSTOPERATIVE CARE

After the VARD procedure, antibiotic treatment should be continued. The antibiotics are continued until the patient is afebrile for 24 hours and white blood cell count is normal. Culture results should be analyzed and antibiotic

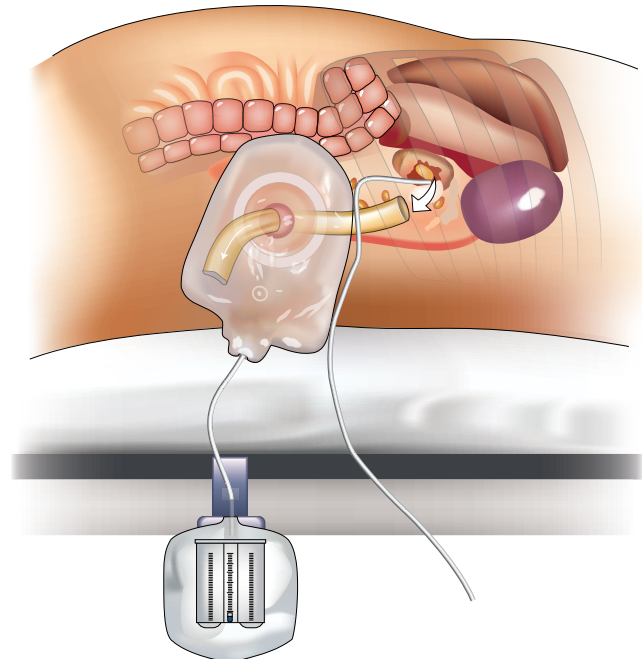
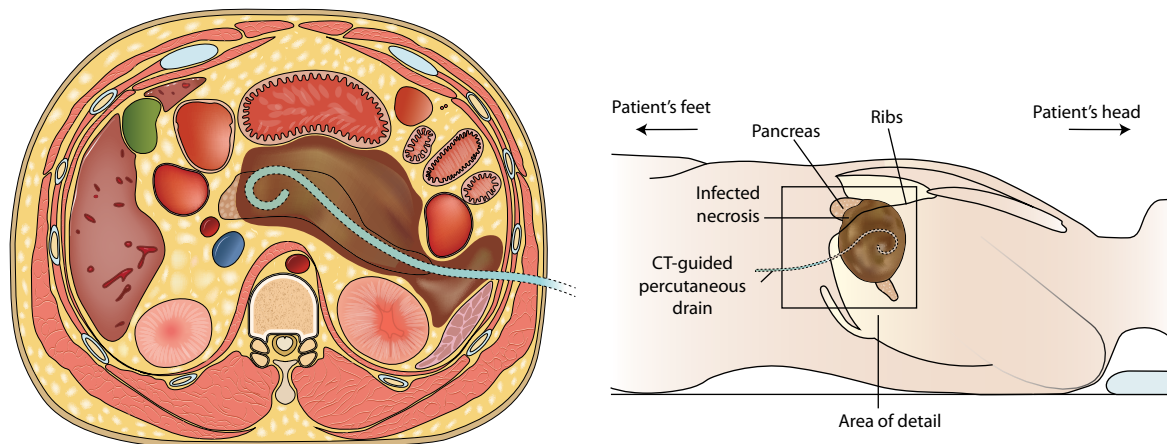


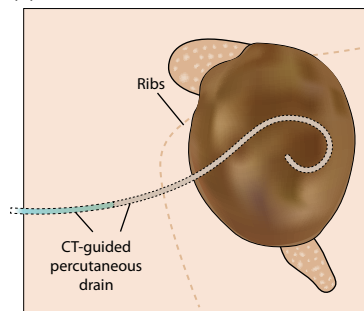
Figure 111.7 Postoperative lavage system.

adjustments made. Percutaneous drains should be continuously infused with 2–4 L of saline per 24 hours. The lavage fluids should be collected in a Foley urimeter. Lavage should be continued until the patient's clinical condition has clearly improved and the lavage fluid is clear, then the drains should stay *in situ* and placed to gravity drainage. If postoperative bleeding is noted (10%–15% of patients), the drains should be clamped at bedside and the interventional radiology alerted. Two weeks after the VARD procedure, a CT scan is performed to localize possible undrained collections. Pancreatic fistulas are a commonly observed complication and occur in 25% of patients.

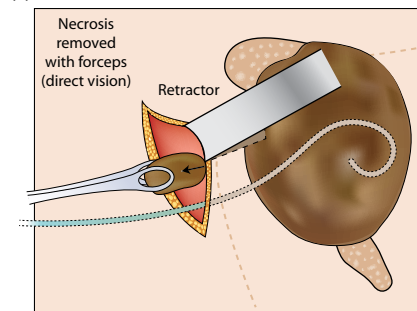
(a)



(b)



(c)



(d)

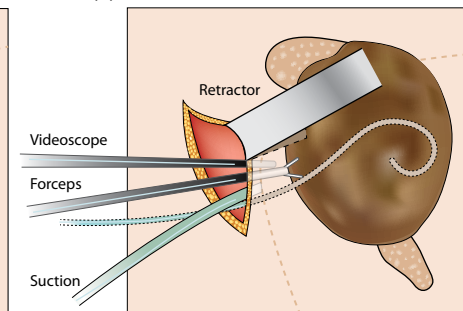


Figure 111.8 PCD and VARD. (a) Cross-sectional image and torso depicting a peripancreatic collection with fluid and necrosis. The preferred access route is through the left retroperitoneal space between the left kidney, dorsal spleen, and descending colon. A percutaneous drain is inserted into the collection to mitigate sepsis and postpone or even obviate necrosectomy. The area of detail is shown in (b). (c) A 5 cm subcostal incision is made, and the previously placed percutaneous drain is followed into the retroperitoneum to enter the necrotic collection. The first necrosis is removed under direct vision with long grasping forceps. This is followed by further debridement under videoscopic assistance (d). (From Van Santvoort HC et al. *Gastroenterology* 2011;141[4]:1254–63; Van Brunschot S et al. *Clin Gastroenterol Hepatol* 2012;10[11]:1190–201.⁹)

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Pediatric laparoscopy and endoscopy



Felice Fontana (medical director) and Clemente Susini (artist), *Venus*, wax anatomical model with organs formed after the *Medici Venus*, ca. 1784–88. Wax, oil, lard and resin, and pigments; glass eyes, human hair; life-size. Collection of anatomical wax models of the Josephinum, Vienna. (Image courtesy Josephinum, Ethics, Collections and History of Medicine, MedUni Vienna, photographed by Alexander Ablogin.)

Never was there a more perfect marriage of the beautiful and the grotesque, sensuous and morose, than wax anatomical Venuses. These idealized female figures attracted a great deal of medical and popular attention during the eighteenth and nineteenth centuries, no doubt because they appealed to human desires, both macabre and erotic. With their tousled hair and euphoric expressions, the figures enticed curious onlookers eager to catch a glimpse. Some were even adorned with jewelry, like this one with a pearl necklace, and laid

upon a silken pillow, hand clutching a voile. Yet, they were always held at a distance, visible only beneath a glass case.

However dramatic the wax Venuses may appear from the exterior, the models hold further mysteries within. Beneath their removable breastplate are “dissectable” inner organs, often including a curled fetus, which were used to demonstrate anatomy. This enabled the medical community to share anatomical discoveries with large crowds without the need for a human cadaver. During the nineteenth century,

they became centerpieces for museum exhibitions and itinerant demonstrations—in particular the fine examples made in Florence like the one pictured above.

This model can be found at the Josephinum at the Medical University of Vienna, which houses the extensive collection of wax anatomical and obstetric models of Holy Roman Emperor Joseph II (1741–90). Inspired by the models in La Specola natural history museum in Florence commissioned by his brother Leopold II (the Grand Duke of Tuscany who succeeded him as emperor), Joseph II ordered 1,192 models

for use in teaching and public display. They were produced by expert modeler Clemente Susini under the supervision of director Felice Fontana and anatomist Paolo Mascagni in Florence between 1784 and 1788. The models that survived the trip over the Alps to Vienna were housed in rosewood and Venetian glass display cases, filling six rooms of the Josephinum, where they remain today.

Joanna Ebenstein, The Anatomical Venus: Wax, God, Death & the Ecstatic (New York: DAP, 2016).

Pediatric laparoscopy: General considerations

SEBASTIAN K. KING AND JACOB C. LANGER

INTRODUCTION

Although the use of laparoscopy in children was first described over 45 years ago, it took more than two decades for the techniques to be embraced by even a small number of early adopters.¹ Significant advances in laparoscopic optics and the miniaturization of surgical instruments, increased anesthetic experience with laparoscopy, and a developing body of literature supporting laparoscopy were observed first in adult, then pediatric, practice. The establishment of the International Pediatric Endosurgery Group (IPEG) in 1991 provided the opportunity for interested surgeons, as well as industry partners, to further the field of pediatric laparoscopy.² The following quarter-century has led to significant, and often unexpected, advances in the utilization of laparoscopy in adolescents, children, infants, and neonates.

This chapter focuses on (1) physiological differences between pediatric and adult patients; (2) a spectrum of surgical conditions amenable to laparoscopic approach in pediatric patients; (3) anatomical considerations and intraoperative heuristics specific to pediatric laparoscopy; (4) limitations in training for pediatric laparoscopy; and (5) evidence for best practice in pediatric laparoscopy.

PHYSIOLOGICAL DIFFERENCES BETWEEN PEDIATRIC AND ADULT PATIENTS

Insufflation pressure and volume

Pediatric patients require smaller volumes of insufflating gas to produce an appropriate pneumoperitoneum. Whereas an adult patient requires 2.5–5 L of gas, a 10 kg infant requires only 0.9 L, and neonatal requirements are even smaller.³ As insufflation is delivered using puffs of gas, rather than as a continuous stream, it is important to minimize the flow rate in neonates and infants to prevent excessive intraperitoneal

pressures following the initial delivery of gas. While insufflation flow rates and the desired intraperitoneal pressures must be adjusted accordingly, there are limited data in the pediatric population to guide these decisions.

The most commonly used gas for insufflation remains CO₂. The advantages of CO₂ include rapid absorption and minimal effects following intravascular embolization. However, the ability to eliminate CO₂ during laparoscopy is age dependent.⁴ The younger the patient, the greater the proportional absorption, and thus a greater need for increased minute ventilation intraoperatively.

A significant side effect of CO₂ absorption is increased cerebral blood flow, which has been noted in the middle cerebral arteries of young children during laparoscopy.⁵ Although the trajectory in cerebral blood flow velocity is steeper in those with transperitoneal laparoscopy when compared with retroperitoneal laparoscopy, the velocity plateaus after 8 minutes.⁶

A potentially life-threatening complication of laparoscopy in the pediatric population is intravascular air embolization. The risk may be ameliorated by completely priming the laparoscopic tubing with CO₂ prior to connection to the port.⁷ This is of far greater significance in the pediatric patient as the absorptive capacity of the peritoneum is greater than in adults, and the volumes required for embolization are far smaller than in adults.

PROCEDURES COMMON TO ADULT AND PEDIATRIC PATIENTS

There are many laparoscopic procedures that are performed in both pediatric and adult practice. These include fundoplication, splenectomy, cholecystectomy, small bowel resection, appendectomy, colon resection, bariatric surgery, Heller myotomy for achalasia, ovarian cystectomy, and inguinal hernia repair (discussed elsewhere). While the basic

approaches to these conditions are usually similar between pediatric and adult patients, some specific differences significantly influence the surgeon's decision-making. Several examples are illustrated in the following sections.

Fundoplication

In adult practice, fundoplication is predominantly used for severe gastroesophageal reflux that remains resistant to medical therapy. Patients often have associated complications of weight loss, esophagitis, and in severe cases, recurrent aspiration. However, the majority of adult patients are neurologically normal with no clear predisposing factor for their reflux.

In pediatric practice, a significant proportion of patients undergoing fundoplication have associated comorbidities, such as neurodevelopmental delay or previous repair of esophageal atresia or diaphragmatic hernia.⁸ These predisposing conditions profoundly influence the diagnostic workup and intraoperative approach.⁹ Patients require preoperative imaging (to exclude impaired oropharyngeal coordination, esophageal stricture, and intestinal malrotation), gastric emptying studies (to exclude abnormal foregut motility), and a trial of alternative feeding regimens (including placement of a jejunal tube) to determine the likely efficacy of the fundoplication.¹⁰

Consideration must also be given to placing a gastrotomy at the time of fundoplication, as many patients will be reliant on tube feeding for their ongoing enteral intake. A proportion of patients will have a previously formed gastrotomy prior to their fundoplication, which often compromises the intraoperative visualization.

Bariatric surgery

Bariatric surgery in the adolescent population remains controversial. While gastric band placement was initially the most commonly performed procedure in adolescents due to its reversibility,¹¹ the gastric sleeve and the Roux-en-Y gastric bypass procedures have gained in popularity and are likely more effective in the longer term.¹² Issues such as long-term vitamin deficiency in noncompliant teenagers and a high incidence of pregnancy in adolescents post-bariatric surgery must be taken into consideration. Also, since most pediatric surgeons only perform small numbers of bariatric procedures per year, it is probably best for pediatric programs to be affiliated with high-volume adult surgeons.¹³

PROCEDURES UNIQUE TO THE PEDIATRIC POPULATION

Hirschsprung disease

Hirschsprung disease is characterized by distal colonic aganglionosis, leading to functional obstruction. While

this was previously managed with a preliminary stoma, followed by repair in two or three stages, the approach has evolved to one stage over the last 20 years. Georgeson et al.¹⁴ first described a laparoscopic approach in 1995, and De la Torre and Langer subsequently described a transanal approach.¹⁵ Both techniques led to significant reduction in length of admission and analgesic requirements. The combined approach of colonic biopsies and mobilization of the distal colon using laparoscopy or an umbilical incision, with transanal dissection of the distal rectum, is now used worldwide.¹⁶

Anorectal malformations

Georgeson et al.¹⁷ also revolutionized the approach to high anorectal malformations by describing laparoscopic dissection of the rectum down to its confluence with the urinary tract. Refinements over the subsequent 15 years have seen a targeted utilization of laparoscopy for these malformations. Most laparoscopic surgeons now limit this technique to male patients with a fistula to the bladder neck or prostate, and female patients with a high cloacal malformation. However, the long-term benefits of this technique remain to be determined.¹⁸

Pyloric stenosis

Laparoscopic pyloromyotomy was first described in 1990 and was, consequently, one of the first operations approached laparoscopically in infants. Almost 20 years later, Hall et al. compared open versus laparoscopic pyloromyotomy in a large, multicenter, international, randomized double-blind controlled trial,¹⁹ and found a statistically significant reduction in time to full enteral feeds and length of postoperative stay with similar rates of intraoperative and postoperative complications. Despite these findings, there remains reluctance to perform laparoscopic pyloromyotomy in many pediatric centers due to a concern that the rate of incomplete pyloromyotomy and mucosal perforation may be higher.²⁰

Biliary atresia and choledochal cyst

Laparoscopic approaches have been described for the Kasai procedure and for excision of choledochal cyst. Laparoscopy has the advantages of excellent visualization, avoidance of a large subcostal incision, and a potential reduction in scarring (which is particularly beneficial if the patient ultimately requires liver transplantation). For biliary atresia, some authors have suggested that outcomes may in fact be worse with the laparoscopic approach, and utilization of laparoscopy for this condition remains limited.²¹ For choledochal cyst excision, there is controversy whether reconstruction should be done as a choledochoduodenostomy or a

Roux-en-Y choledochojejunostomy.²² The inherent technical difficulties, as well as the relative rarity of the condition (1 in 10,000) in the Western world, have limited the opportunities for most surgeons to gain expertise in this procedure. However, there are centers in Asia that have extensive experience and have reported excellent outcomes for laparoscopy.²³

Intestinal rotation abnormalities

Intestinal rotational anomalies are defined as incomplete rotation of the duodenum and cecum (midgut) around the superior mesenteric vessels, and range from nonrotation to normal rotation. Malrotation is the most important clinical entity, as the close proximity of the duodeno-jejunal junction to the cecum leads to a narrow-based mesentery, which increases the potential for midgut volvulus, intestinal ischemia, midgut loss, and even death in extreme cases. Malrotation is corrected with the Ladd procedure, which includes widening of the mesentery, prophylactic appendectomy, and placement of the midgut into a position of nonrotation.

In the acute setting of malrotation and volvulus, with intestinal ischemia, most surgeons will still approach the Ladd procedure via a laparotomy.²⁴ However, in infants and children presenting with intermittent episodes of bile-stained vomiting, or in whom an upper gastrointestinal contrast study has confirmed a rotational anomaly, laparoscopy provides excellent visualization of the mesenteric base.²⁵ If a narrowed base is found, then widening of the mesentery may be performed and appendectomy completed. Long-term studies are still required to confirm whether the laparoscopic approach is as effective as open Ladd procedure in preventing midgut volvulus. Some authors worry that the laparoscopic approach may lead to less adhesion formation, which they believe prevents subsequent volvulus. However, others believe that it is the widening of the mesentery that prevents volvulus, and that prevention of adhesion formation may decrease the known 15%–25% incidence of adhesive bowel obstruction after open Ladd procedure.²⁶

Congenital diaphragmatic hernia

Both forms of congenital diaphragmatic hernia are amenable to laparoscopic repair. Although the Bochdalek hernia (posterolateral defect) may be repaired laparoscopically in older children, it is more commonly repaired in neonates using a thoracoscopic approach, as laparoscopic visualization of the defect may be difficult after reduction of the viscera into the abdomen. A minimal access approach should only be used for children with minimal pulmonary compromise, and has been associated with a higher recurrence rate than the open technique.²⁷ The Morgagni hernia (anteromedial defect) is technically easier to repair than the Bochdalek hernia, although larger defects may require patch repair.

Duodenal atresia

Duodenal atresia is a congenital obstruction that is typically diagnosed antenatally, or postnatally on the first day of life. Laparoscopic repair, in most cases using a duodeno-duodenostomy, has been described by a number of authors. Although initial reports were not encouraging, increased expertise in neonatal laparoscopy and improved surgical instrumentation have led to a rethinking of the role for laparoscopy in this operation.²⁸

Necrotizing enterocolitis

Necrotizing enterocolitis (NEC) remains the most common cause of death in surgical neonates. In the last decade, there has been increasing evidence for the role of laparoscopy in guiding decision-making for neonates with presumed NEC.²⁹ In some patients, laparoscopy has enabled identification of the affected intestinal segment and facilitation of stoma formation. Delayed laparoscopic resection of NEC-associated strictures in neonates has also been described.³⁰ While the optimal management of NEC remains uncertain and the focus of ongoing multicenter international studies, it is likely that laparoscopy in NEC will be utilized by few surgeons, typically in large pediatric centers.

ANATOMICAL CONSIDERATIONS AND INTRAOPERATIVE HEURISTICS

The anatomical differences between adults and children are well known and are particularly marked in neonates and infants. The limited working space that results from the small abdominal cavity, as well as the relatively large liver and bladder, requires greater spatial awareness to ensure that iatrogenic injuries are minimized.³¹ Port placement is critical, as the limited working space demands accurate triangulation to reduce the risk of hindering progress with inadvertent instrument clashes.

Improvements in surgical instrumentation have led to shorter and thinner devices, which have helped overcome some of the limitations of the available working space. Many surgeons place instruments directly through the abdominal wall without ports in neonates and infants (**Figure 112.1**).

Surgical heuristics, and prevention of back and neck pain, may also be improved by placing smaller patients across the operating table (**Figure 112.2**). An often forgotten aspect of port placement is how the wounds will migrate with increasing age. This is of particular importance if the port site is to be used for formation of a gastrostomy, ileostomy, or colostomy. As the wounds in the upper abdomen will migrate toward the costal margin, it is critical that a long-term gastrostomy site is not placed in such a way that it will cause discomfort and kinking at the lower rib margin as the patient ages.



Figure 112.1 Many surgeons place instruments directly through the abdominal wall without ports in neonates and infants.



Figure 112.2 Surgical heuristics, and prevention of back and neck pain, may also be improved by placing smaller patients across the operating table.

TRAINING OPPORTUNITIES: HOW TO REDUCE THE PROLONGED LEARNING CURVE

The acquisition of laparoscopic skills for the majority of pediatric surgeons has been hampered by small case numbers for most conditions, slow advances in miniaturization of instruments, and a reluctance by many to embrace new technologies.^{32,33} While skilled in laparoscopic appendectomy and fundoplication, many pediatric surgeons continue to perform many procedures using an open approach despite well-described laparoscopic approaches for pyloromyotomy, splenectomy, and other common operations.

The limitation of small case numbers may be somewhat overcome by the use of laparoscopic trainers and/or simulators. The Pediatric Laparoscopic Surgery (PLS) simulator

has been validated as a teaching tool for pediatric minimal access surgery.^{34,35} The advantages of the PLS simulator have included reproducibility and training in key operative steps, including extracorporeal and intracorporeal suturing. In addition, the use of learning curve evaluation (the cumulative summation method) now allows surgeons and trainers to accurately assess the key components of an operative technique and to study improvements in technical proficiency with greater fidelity.³⁶ With these and other tools, it is hoped that laparoscopy for rarer conditions will become the standard, rather than the exception, for pediatric surgeons.

EVIDENCE OF BEST PRACTICE IN PEDIATRIC LAPAROSCOPY

While the uptake of pediatric laparoscopy has increased in the last decade, there has been a paucity of objective prospective data to support its place in best practice. This lack of data was noted in 2008 by Orzech et al. in their systematic review focused on levels of evidence for minimal access pediatric surgery.³⁷ A recent Cochrane review of the use of minimally invasive surgery for the treatment of solid abdominal and thoracic neoplasms in children highlighted the ongoing lack of both randomized controlled trials and controlled clinical trials in these conditions.³⁸ The need for better pediatric evidence is clear.

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Laparoscopic hernia repair in children

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INTRODUCTION

Laparoscopy has at once revolutionized and complicated the treatment of pediatric abdominal wall hernias. Laparoscopic inguinal herniorrhaphy was first introduced in 1998 by Schier,¹ but the use of laparoscopy as an adjunct to the diagnosis of contralateral metachronous hernias was first introduced in the early 1990s.^{2,3} Laparoscopic hernia repair in children is essentially a peritoneal repair, and thus differs from that in adults, which comprises a wide variety of peritoneal closures, obliteration, pelvic floor repair, and so on. In addition, pediatric laparoscopic repair is done exclusively as a transperitoneal approach and virtually never includes mesh placement. This chapter focuses on technical aspects of laparoscopic inguinal herniorrhaphy in pediatric patients, with a brief discussion of other types of hernia repair (femoral, traumatic ventral, etc.). It also briefly reviews transinguinal or transabdominal laparoscopy in the diagnosis of a contralateral patent processus vaginalis.

LAPAROSCOPIC INGUINAL HERNIA REPAIR IN CHILDREN

An overwhelming majority of pediatric inguinal hernias are indirect, resulting from a patent processus vaginalis, and laparoscopic approaches have been designed to obliterate this defect. The operation may be performed either laparoscopically, or percutaneously under laparoscopic guidance. The laparoscopic technique currently practiced by most pediatric surgeons involves suture closure of the open inguinal canal, but some evidence suggests that herniotomy (i.e., division of the hernia sac rather than ligation) or scarring of the peritoneal lining in an effort to promote inflammation and scarring may be as effective as formal ligation.^{4,5}

Technique

Laparoscopic inguinal herniorrhaphy requires general anesthesia and a typical sterile preparation and draping of the mid and lower abdomen. Some surgeons include a full preparation of the genitalia, particularly in boys, to allow examination of the scrotum or labia as necessary. Preoperative antibiotics are not indicated. It is helpful to have patients urinate immediately prior to operation. In newborns and infants, the bladder may be emptied by manual pressure over the lower abdomen after anesthesia induction.

The peritoneal cavity is typically accessed with a 5 mm umbilical trocar and a 30° laparoscope. In smaller children the authors prefer the use of a 2.7 mm 30° camera placed through a 3 mm umbilical trocar. Some surgeons use a small camera through a needlescopic approach, eliminating the need for umbilical fascial closure. With the patient in slight Trendelenburg position, the inguinal canals are inspected and a decision is made regarding the need for contralateral repair in cases of clinically unilateral hernias (Figures 113.1 and 113.2). An additional 3 mm instrument (Maryland dissector, or laparoscopic needle driver if intracorporeal repair is undertaken) is introduced through a stab incision in the midclavicular line at about the level of the umbilicus on the side of the clinically apparent hernia. For bilateral hernias, a single instrument suffices and can reach either inguinal canal.

The initial step is to create cautery injury to the peritoneum at the inguinal ring from about 8 to 4 o'clock, carefully avoiding damage to the spermatic cord structures as well as other internal organs (Figure 113.3). In rare cases of hernia incarceration or the discovery of a sliding hernia, the canal contents must be reduced adequately prior to cauterizing the ring. Hydrodissection of the ring is helpful prior to placing circumferential sutures and is accomplished by passing a small needle through the skin overlying the internal ring and in

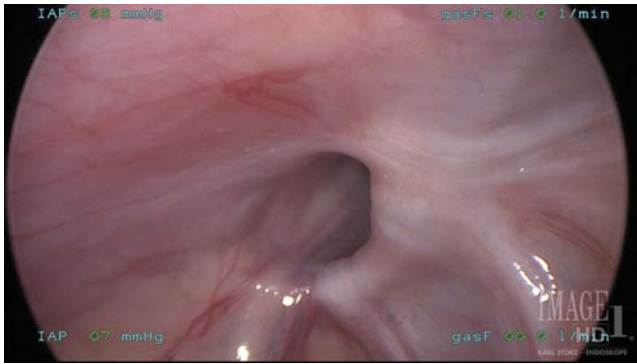


Figure 113.1 Patent left processus vaginalis with clinical hernia.



Figure 113.2 Fused right processus vaginalis.

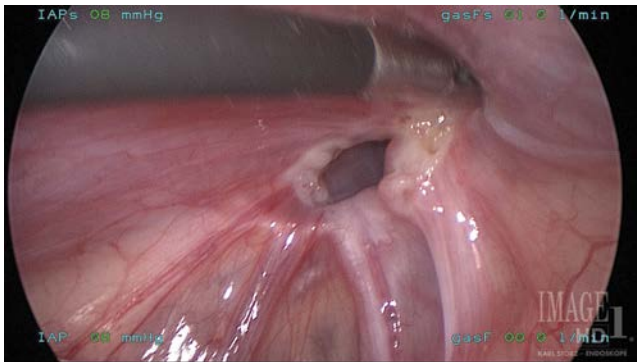


Figure 113.3 Cautery injury created in peritoneum around internal inguinal ring.

both medial and lateral directions and gently injecting local anesthetic (without added epinephrine) in the subperitoneal space ([Figure 113.4](#)). The surgeon should be careful to place the needle at the correct level in order to make direct, non-angled entry into the peritoneal cavity, and should be able to see the needle tip immediately below the surface of the peritoneum. This is particularly useful in the area of the spermatic cord structures, as it allows safe passage of circumferential sutures above the cord structures subsequently.

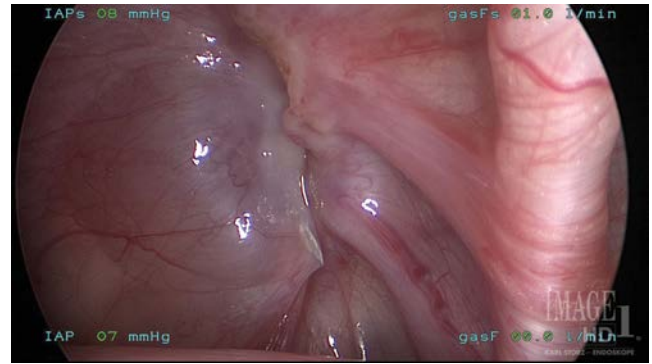


Figure 113.4 Percutaneous hydrodissection lifts the peritoneum off the vas deferens and spermatic vessels.

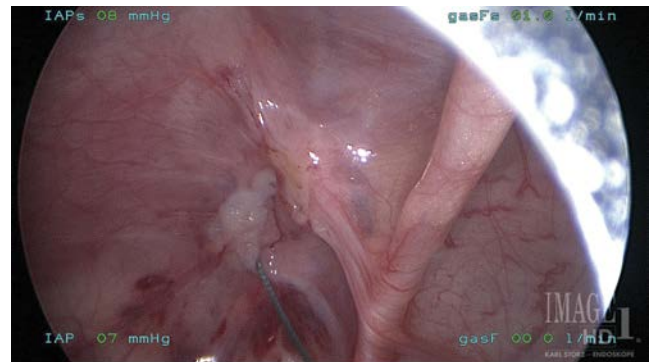


Figure 113.5 Lateral suture loop passed subperitoneally.

Total intracorporeal repair is accomplished by passing a nonabsorbable suture through the entire circumference of the inguinal ring in the subperitoneal plane and securing it (either with a knot-pusher or by adding an additional instrument through a separate stab incision). We prefer the extracorporeal technique, described in detail in several publications.⁶ In one common variation, a 3-0 nonabsorbable braided suture is passed through a slightly bent 18G spinal needle and guided through a small skin nick at the 12 o'clock position laterally in the subperitoneal plane as far as possible, often passing over the spermatic vessels, then exiting through a peritoneal puncture ([Figure 113.5](#)). The previously placed 3 mm instrument can be helpful in lifting up the peritoneum to help guide it over the spinal needle, as well as in pulling in the loop of suture and securing it while the needle is withdrawn over the suture. A second suture is passed through the needle and advanced medially under the peritoneum to complete the subperitoneal suturing of the inguinal ring. Once the needle has traversed the medial half of the ring, it is pushed through the peritoneum to exit within the first loop ([Figure 113.6](#)). The second suture is pulled into the abdominal cavity (making sure that it is within the first loop) and the needle withdrawn. The ends of the first loop are then pulled, snaring the second loop and drawing it out through the skin incision. The surgeon is then left with a double loop

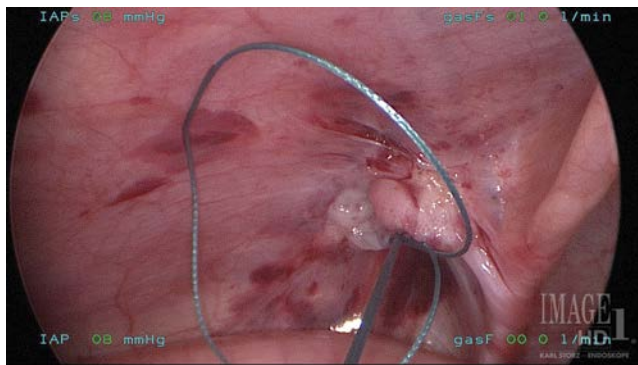


Figure 113.6 Medial suture loop passed subperitoneally and snared by lateral loop.

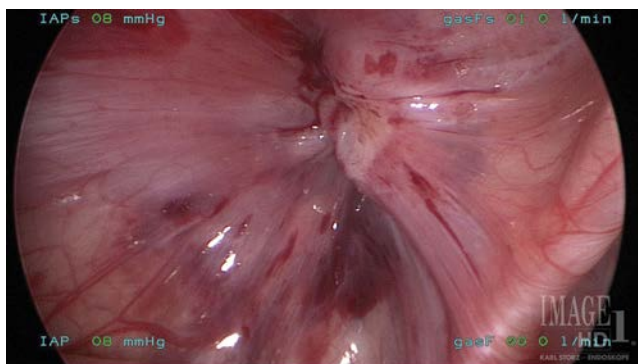


Figure 113.7 Completed inguinal hernia repair.

completely encircling the inguinal ring. The first loop suture is removed, and the second loop cut, allowing the surgeon to tie two separate ties and complete closure of the ring, which can be observed laparoscopically (**Figure 113.7**). It can be helpful to squeeze out carbon dioxide from the scrotum prior to final closure of the inguinal ring.

The knots are completely buried in the skin (it is helpful to pull up the edges of the skin at the skin nick site) and the skin incision closed with tape or skin glue. Should bilateral hernia repair be needed, a mirror image procedure is performed on the contralateral side. After final inspection of the peritoneal cavity, the 3 mm instrument is removed, the peritoneal cavity desufflated, and the umbilical fascia and skin closed.

Special mention should be made of alternative techniques for herniorrhaphy in girls. An inversion technique whereby the most distal aspect of the hernia sac is grasped and forcefully inverted into the peritoneal cavity, followed by suture or ENDOLOOP closure of the sac, was first reported in the late 1990s.¹ Subsequent studies suggested the excision of the redundant sac was important to reduce recurrence rates.⁷ Cauterization of the hernia sac with the creation of an autologous plug is appealing for simplicity and speed and would be theoretically similar to ligation, but long-term results have not been formally reported.

Postoperative care

Laparoscopic hernia repair in children is uniformly an outpatient procedure, except in patients who require extended monitoring on the basis of nonsurgical concerns (most commonly postoperative apnea monitoring following general anesthesia in premature infants). Incisions are typically closed with dissolvable sutures or skin glue, and patients are typically released to unrestricted activity within a week of hernia repair. Except in rare cases, postoperative pain should be managed with acetaminophen and ibuprofen alone.

Complications

Complications from laparoscopic inguinal hernia repair in children comprise three categories: those related to laparoscopic access to the peritoneal cavity; wound infections and incisional hernias common to any incision; and those specifically related to intra-abdominal closure of the inguinal ring.

Laparoscopic access is the first step of myriad intra-abdominal procedures, and most pediatric surgeons are well versed and comfortable in safe needle access for peritoneal insufflation. Patient obesity, previous abdominal operations, and abnormal umbilical anatomy can make access challenging, and potential for damage to viscera or blood vessels certainly exists, with occasionally disastrous consequences.⁸ Fortunately, these are exceedingly rare.

Surgical site infection after open inguinal hernia repair is estimated to be 1%–2%.⁹ Infectious complication rates in laparoscopic repair are even lower.¹⁰

An estimation of actual risk of complication related specifically to inguinal ring closure is hard to glean from the literature but can include abdominal wall hematomas during hydrodissection of the ring and needle passage (particularly if the epigastric vessels are inadvertently punctured), damage to contents of the spermatic cord, inadvertent thermal injury to adjacent structures during electrocautery of the ring peritoneum, and inadvertent puncture injury of surrounding structures during needle passage of circumferential sutures prior to closure.

LAPAROSCOPIC FEMORAL HERNIA REPAIR IN CHILDREN

Femoral hernias are rare in children and may be hard to diagnose preoperatively. Laparoscopy offers an ideal method of diagnosis in distinguishing among different types of pelvic floor hernias (the most common indirect, congenital inguinal hernia versus direct inguinal hernia versus femoral hernia). Several reports have described either totally laparoscopic repairs or laparoscopic diagnosis followed by hybrid repair including directed placement of a mesh plug through a small lower inguinal incision.¹¹

MISCELLANEOUS OTHER ABDOMINAL WALL HERNIAS AND THE ROLE OF LAPAROSCOPY IN THEIR REPAIR

Children may suffer traumatic abdominal wall hernias, epigastric hernias, and rarely Spigelian hernias, along with incisional hernias following prior laparotomy. True laparoscopic approaches have been described for all but the epigastric hernias, with outcome reporting limited by small case number.¹² Nonetheless, they offer the typical advantages of cosmesis, reduced pain, quicker recovery, decreased wound infection rates, and decreased incisional hernia rates over open approaches. Epigastric hernias are usually small, supraumbilical, midline defects of the anterior rectus sheath. Subcutaneous transumbilical minimally invasive approaches have been described¹³ but seem less likely to prove advantageous over open techniques than the other examples in this section.

THE UTILITY OF TRANSINGUINAL OR TRANSABDOMINAL DIAGNOSTIC LAPAROSCOPY

A full discussion of the pros and cons of diagnostic laparoscopy as it relates to the examination of the contralateral inguinal region during repair of a clinically apparent unilateral inguinal hernia is beyond the scope of this chapter. We briefly mention it because many pediatric surgeons still employ this technique during open inguinal herniorrhaphy, introducing a sharply angled telescope through the open inguinal ring in an effort to examine the contralateral inguinal region and assess for patency of the processus vaginalis. Particularly in younger patients, a patent processus may not correspond to a true inguinal hernia, and thus the concern remains that patients undergo unnecessary repairs of a congenital opening that might never be a symptomatic hernia. Various authors have attempted to identify particular characteristics of the processus—width, depth, etc.—in order to distinguish which ones should be repaired,¹⁴ but there is no consensus on this matter. Direct visualization via umbilical laparoscopy does appear to afford a better view of the inguinal region than that via angled telescropy through an inguinal incision.

LONG-TERM RESULTS AFTER LAPAROSCOPIC INGUINAL HERNIA REPAIR

Initial reports of laparoscopic inguinal herniorrhaphy in children were notable for recurrence rates nearly twofold greater than those in open repair (4.1%).¹⁵ Although this tempered early enthusiasm for adoption of laparoscopy, later investigations found no difference in short- and medium-term recurrence rates between open and laparoscopic repairs. Recent large follow-up analyses found an approximately

0.25%–1.4% recurrence rate at 3–5 years' follow-up.^{10,16} Open repair in newborns, particularly in those born prematurely, is associated with a markedly higher recurrence rate,¹⁷ but the same difference has not yet been clearly noted in laparoscopic repairs, suggesting that the latter approach may be particularly well-suited in younger patients.¹⁸

Long-term follow-up studies in patients after open repair are few, but have found a recurrence rate of approximately 1%, overall groin reoperative rate of approximately 8%, and absolute infertility in approximately 3% in 35–50 year follow-up.^{19,20}

Follow-up studies after pediatric inguinal hernia repair focus not only on recurrence but also on assessments of potential damage to spermatic cord structures in boys (i.e., testicular atrophy and infertility due to vas deferens ischemia), as well as postoperative incisional pain, surgical site infection, inguinodynia due to impingement on the ilioinguinal nerve, and long-term cosmetic considerations. Perhaps the greatest support for laparoscopic inguinal herniorrhaphy comes from those who believe that this approach spares trauma to the spermatic cord structures. This seems a teleologically appealing theory but is difficult to study and perhaps impossible to prove.

Some studies have found a slight increase in immediate postoperative pain scores and need for analgesia, perhaps due to the effects of carbon dioxide insufflation or an umbilical rather than inguinal incision, but there appears to be no difference in pain after the immediate (same-day) postoperative period.²¹ Inguinodynia is rarely reported in series examining postherniorrhaphy follow-up, but one might speculate that minimal disruption and ligation of abdominal wall structures aside from the inguinal ring may at least avoid theoretical impingement on the ilioinguinal nerve.

Minimally invasive surgery is commonly thought to confer cosmetic advantages over open surgery, although it is perhaps disingenuous to argue forcefully for the advantages of an umbilical laparoscopic port incision and a 2–3 mm lower abdominal stab incision over minimally detectable incision in the groin.

FUTURE DIRECTIONS

Perhaps the most important future direction in the management of pediatric abdominal wall hernias remains the evaluation of long-term outcomes, principally those related to (1) recurrence and (2) potential damage to the spermatic cord structures. Intermediate-term data in laparoscopic pediatric inguinal herniorrhaphy are promising on both fronts, but data need to be supplemented both by larger numbers (allowing for stratification by patient characteristics and comorbidities) as well as longer follow-up.

Unanswered still is the debate between herniotomy and herniorrhaphy. While division or excision of the hernia sac is accepted in many parts of the world as a preferred alternative to high ligation,^{9,22} pediatric surgeons in the

United States have not adopted this technique. Its potential advantage lies in the minimal dissection necessary, savings in operative time and material cost, and potential reduction even further of the risk of injury to spermatic cord structures.

Finally, the use of an injectable polymer or biological plug to obliterate an open inguinal canal, perhaps under ultrasound guidance, thus obviating the need to perform laparoscopy, appeals from a theoretical standpoint as much as it may cause concern over potential for inflammatory damage to the adjacent spermatic cord structures.²³ Further animal studies may help decide whether this technique is worthy of investigation in humans.

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Laparoscopic treatment of reflux in children

STEVEN ROTHENBERG

INTRODUCTION

Gastroesophageal reflux disease (GERD) is one of the most common foregut disorders seen in infants and children in the United States.¹ The pathological symptoms and complications that result from reflux affect 7%–20% of the pediatric population.² Surgical treatment, consisting of a fundoplication, should be considered if the patient's GERD is refractory to medical therapy, is the root cause of recurrent aspiration or apnea episodes (sudden infant death syndrome or acute life-threatening events [ALTEs]), or in patients with neurologic impairment, failure to thrive, and esophagitis and stricture formation.² An increasing incidence of Barrett's esophagitis is also being documented in children. Another common association has been with the placement of a gastrostomy tube for feeding and a significantly increased risk of GERD.³ Approximately 10%–50% of these patients will eventually require fundoplication. Recent studies have also indicated that GERD may have a more important role in respiratory problems, including the development of long-term severe reactive airway disease. All of these factors have resulted in a large increase in the number of fundoplications performed.^{4–6}

WORKUP

The evaluation of these patients varies somewhat with age; however, as opposed to adults, all children should have an upper gastrointestinal (UGI) series to rule out an anatomic abnormality such as malrotation, duodenal web, or stricture. In infants with ALTEs, the clinical symptoms and a UGI showing severe reflux are often enough information to warrant a fundoplication. Infants with known GERD with failure to thrive despite maximal medical management may also require no further testing. Most other patients are evaluated with a pH or impedance probe to quantify the degree

of reflux, and an increasingly large percentage are undergoing upper endoscopy and biopsy. In infants, milk or food allergies may often present as reflux, and these issues should be sorted out before surgical intervention.

Bronchoscopy with bronchialalveolar lavage (BAL) is helpful in patients with reactive airway disease or recurrent respiratory infections. A high level of lipid-laden macrophages is indicative of recurrent aspiration. Some like to obtain gastric emptying studies, but in general, these tests add little information in patients with primary reflux, and a gastric emptying procedure is rarely indicated in a patient undergoing a primary fundoplication.

TECHNIQUE

Depending on the size of the child, the patient is supine or in a modified dorsal lithotomy position at the end of the table. The surgeon stands at the foot of the table at the infant's feet or between the legs in a larger child. The monitor should be placed over the child's head to allow for the best ergonomic setup for the procedure (**Figure 114.1**). The assistant is on the surgeon's left and controls the camera and the stomach retractor.

A five-trocar technique is routinely used. Depending on the size of the child, trocars are 3 or 5 mm in size. Some favor simple stab wound incisions rather than ports. Trocars are placed in the umbilicus (camera port), the right and left mid-quadrants (the working ports), the right upper quadrant (liver retractor), and the left upper quadrant (stomach retractor and gastrostomy tube site) (**Figure 114.2**). The abdomen is insufflated through the infraumbilical ring incision using a Veress needle or Hassan technique. Insufflation pressures between 10 and 15 mm Hg are used depending on the size and respiratory status of the patient.

Selection of instruments and trocar size are also dependent on the size of the child. In general, for infants and

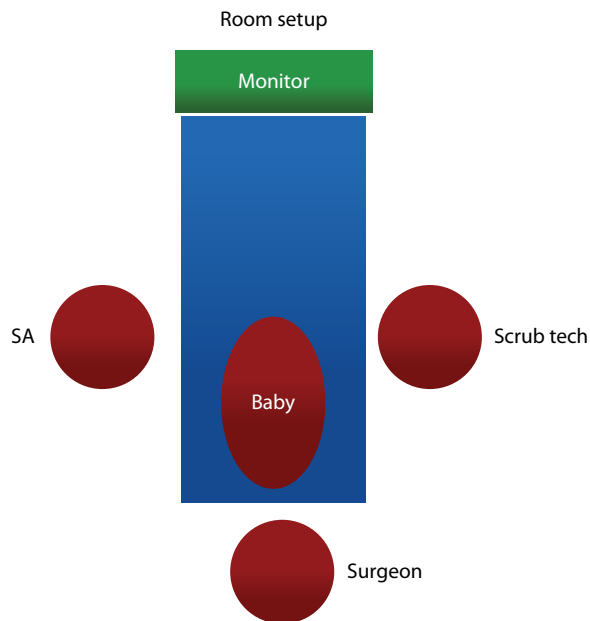


Figure 114.1 Room setup for a pediatric laparoscopic fundoplication. The infant is placed at the foot of the bed in a frog leg position. Larger patients are placed in stirrups to allow the surgeon to stand between the feet.

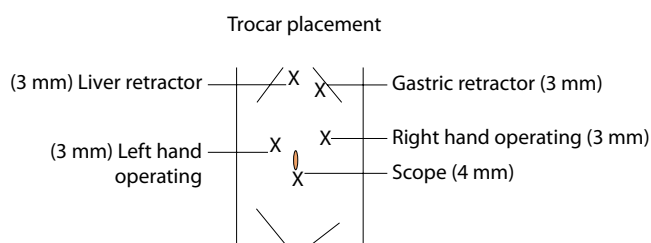


Figure 114.2 The camera port is placed at the umbilicus. Right- and left-hand operating ports are placed in the right and left mid quadrants. The liver and stomach retractors are placed closer to the costal margin.

children less than 20 kg, 3 mm instruments of 18–20 cm length are appropriate. For children over 20 kg, standard-length 3 or 5 mm instruments are appropriate. A 4 or 5 mm 30° scope is used. The choice of energy source used is surgeon dependent. In small infants and children, monopolar cautery is usually sufficient to perform the needed dissection as well as divide the short gastric vessels. This can be achieved with a simple 3 mm hook. Alternatively, a new 3 mm bipolar vessel sealing and dissecting instrument is now available and eliminates the risk of energy spread associated with monopolar cautery. In larger patients with more fat surrounding the short gastric vessels, one of the energy-sealing devices greatly enables this portion of the dissection.

PROCEDURE

The left lobe of the liver is retracted superiorly to expose the gastroesophageal (GE) junction. In most cases, the liver can be adequately retracted by using a locking Babcock clamp to grasp the diaphragm, through the right upper quadrant port. This port should be positioned so that the instrument enters the abdomen just to the patient's right of the falciform ligament just below the tip of the liver (**Figure 114.3a and b**). This is a self-retaining retractor, as the weight of the handle

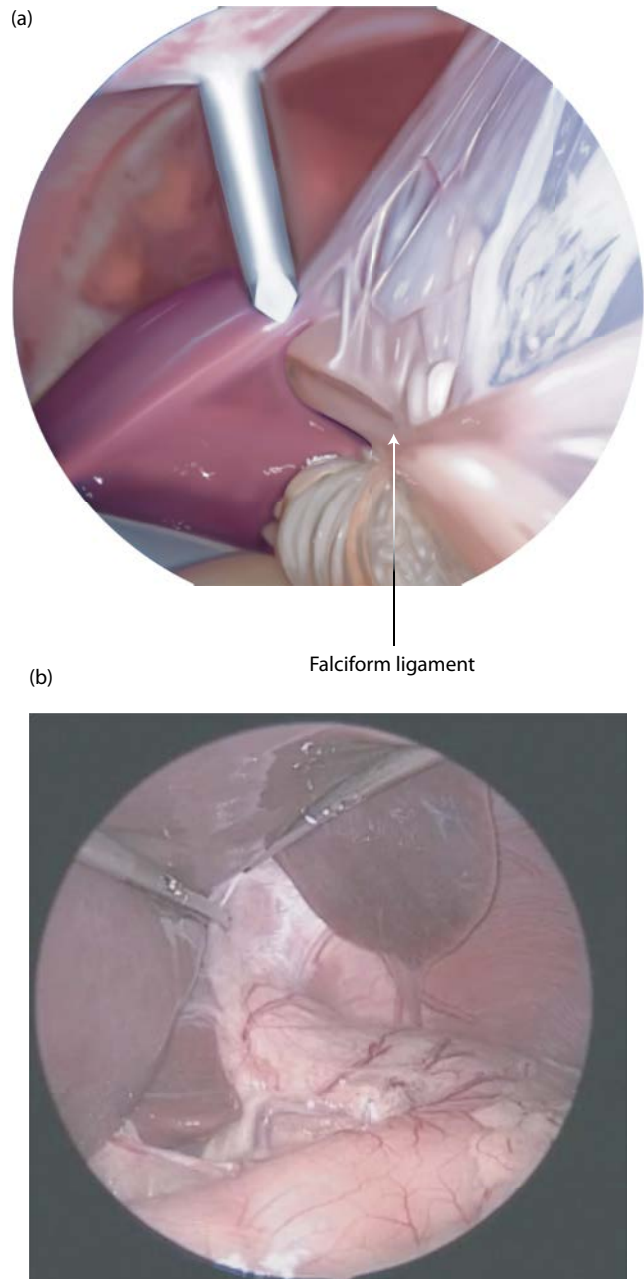


Figure 114.3 (a) The liver retractor (a Babcock) is placed at the liver edge just to the patient's right of the falciform ligament. (b) The Babcock is used to grasp the crus at the top of the hiatus to act as a self-retaining retractor.

suspends the liver. Alternatively, a snake or fan retractor can be used and attached to a self-retaining arm attached to the table, although these are more cumbersome.

A second Babcock or atraumatic clamp is placed through the left upper quadrant port to retract the stomach as necessary. When working at the hiatus, the stomach is retracted inferiorly and laterally to help expose the esophagus. While mobilizing the short gastric vessels, the stomach is grasped near the greater curve and retracted medially to better expose them.

The procedure is started by dividing the gastrohepatic ligament using scissors, sealer, or hook cautery. The hepatic branches of the vagus nerve may be taken without untoward effects. In about 25% of cases, an aberrant left hepatic artery arises off the left gastric artery and if present should be left intact. The peritoneum overlying the right crus is cleared to allow for adequate mobilization of the intra-abdominal esophagus. The stomach is then retracted medially with the left upper quadrant Babcock, and the upper short gastric vessels and posterior attachments of the stomach are divided. This allows clear delineation of the left crus and makes development of the retroesophageal window much safer. Division of the short gastrics also ensures the formation of a tension-free wrap.

A retroesophageal window is then developed from the patient's right side, taking care not to injure the posterior vagus nerve. The nerve should be left adjacent to the esophagus. Mobilization of a good length of intra-abdominal esophagus (4–6 cm depending on the size of the child) is critical to ensure the formation of an adequate wrap. Once the esophageal mobilization is complete, the clamp in the left upper quadrant port is placed behind the esophagus and used to expose the esophageal hiatus. At least one crural stitch should be placed in all cases using a strong nonabsorbable suture (2–0 ETHIBOND), even if the hiatus looks to be of normal size. The mobilized portion of the posterior fundus is then brought around behind the esophagus to form a 360° wrap. The anterior wall of the fundus is brought anterior to the esophagus to complete the fundal wrap positioned at approximately the 11 o'clock position. The wrap can be formed around an intraesophageal stent, size dependent on the size of the patient, to ensure the wrap is not too tight. However, if adequate mobilization of the fundus is achieved, this is rarely a concern. Dysphagia is more likely to occur if there is a hiatal hernia and the crura are closed too tight.

The wrap is made 2–3 cm in length and consists of three sutures going from the stomach, to the anterior wall of the esophagus, to the wrapped portion of the stomach (**Figure 114.4**). It is important to include the esophagus in each suture in order to prevent a slipped Nissen. The top stitch may also include the anterior diaphragmatic rim, a step that may aid in preventing the wrap from herniating up into the mediastinum.

A gastrostomy tube may also be placed if needed, utilizing the left upper quadrant port (**Figure 114.5**). Gastrostomy tubes should not be placed unless they are needed for feeding; it is not necessary to place one simply to vent the stomach.

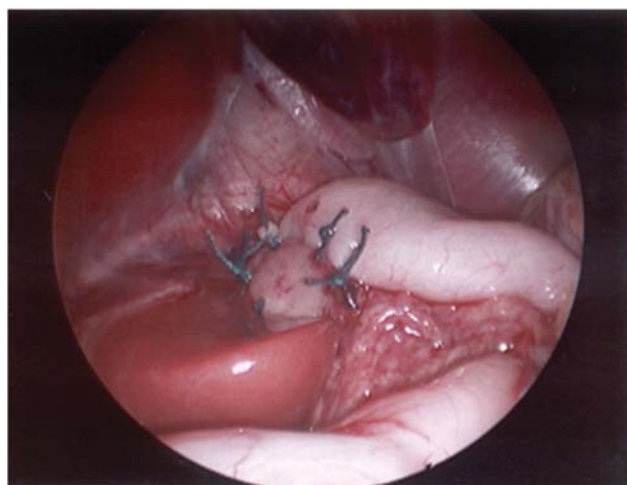


Figure 114.4 The completed wrap with the stitches at the 11 o'clock position on the esophagus to prevent twisting or torque on the esophagus.

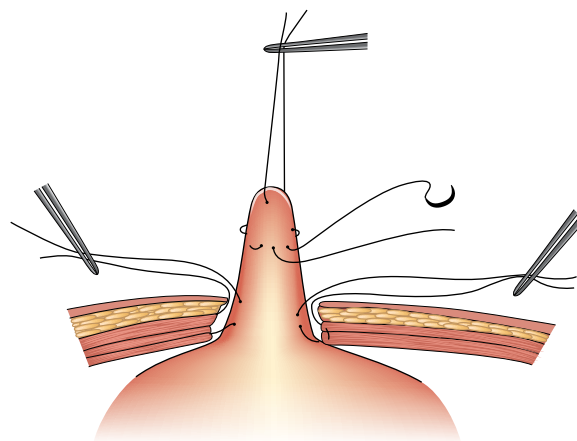


Figure 114.5 Technique for placing a gastrostomy button through the left upper quadrant trocar site.

In general, oral feeds are started immediately postoperatively. The patients are placed on clear liquids for the first 24 hours and then on a soft diet for 3–5 days until most postoperative swelling is gone. They are then allowed a regular diet, although in small children the parents are counseled to keep everything bite size until the child understands that he or she should chew the food well.

DISCUSSION

Laparoscopic Nissen fundoplication (LNF) has changed the way GERD is managed in both adults and children. The first LNF was described in 1991 by Dallemagne⁷ followed 2 years later by Georgeson and then Lobe,⁸ advocating this approach in children. Low morbidity of the procedure has

led to wide acceptance for the surgical treatment both by physicians and patients, and LNF has become the standard of care for the treatment of GERD. We reported our 20-year experience largest series with 2,018 LNFs in the pediatric population in 2013 with no procedural mortality.⁹ Clinical results were comparable to the traditional open fundoplication with a recurrence rate of only 4.5% and with a significant decrease in morbidity and hospitalization. Pulmonary benefits afforded by this minimally invasive approach potentially play an even greater role in neurologically impaired children, ex-preemies, and the intensive care population, where the complication rates are higher and the ability to avoid respiratory complications has an additional benefit. We have also shown the great benefit in the treatment of patients with reactive airway disease in terms of treating their reflux, but more importantly in an improvement in the clinical manifestations of their asthma.¹⁰ Recurrence rate and need for redo procedure in patients younger than a year of age is higher (6.4%), possibly due to immature tissues and differential growth.¹¹ However, the growth and respiratory advantages of fundoplication in this population outweigh the minimal risk and morbidity associated with redo procedures. The laparoscopic approach also provides improved and magnified visualization, decreasing the chances of vagus nerve injury, which has been shown to decrease the incidence of bloating, dysphagia, and other symptoms associated with fundoplication postoperatively. Many of our older patients provided a history of stomach flu leading to severe retching prior to the recurrence of GERD-related symptoms, which has been shown previously to be an important contributor in early failures.

The key to a good outcome and a relatively low recurrence rate is secondary to technical considerations and surgeon experience. Key points include adequate creation of intra-abdominal esophagus, limited hiatal dissection leaving the phreno-esophageal ligament, and creation of a tension-free and appropriate orientation and positioning of the wrap. Therefore, the right crus must be clearly identified and dissected out so that the GE junction is clearly identified and an adequate length of intra-abdominal esophagus is confirmed. Dissection should not extend through the phreno-esophageal ligament and up into the hiatus, as this increases the risk of secondary hiatal hernia formation. A failure to adequately identify the GE junction and acquire

a significant length of intra-abdominal esophagus results in a wrap being performed too low. This complication has been presenting itself more commonly in the last 5 years in patients referred from outside institutions. The findings at the time of surgery are an intact wrap but one at or below the GE junction. These wraps have proven to be incompetent.

A crural repair should be performed in all cases to decrease the incidence of hiatal separation and hiatal hernia formation. If there is a large defect or a recurrent hernia, the repair should be reinforced with Teflon pledgets. The upper short gastric vessels should be divided to allow for a tension-free wrap, and orientation of the wrap should be at 11 o'clock on the esophagus to prevent twisting or torsion of the esophagus. The wrap should be loose and short (2 cm or less). If these guidelines are followed, the morbidity of the procedure becomes minimal, and the advantages in most patients are significant.

It is clear that the laparoscopic Nissen is an imperfect operation, but if an experienced laparoscopic surgeon performs the procedure, the procedure is safe and effective. It requires less than an hour of operative time, only an overnight hospital stay, and has minimal morbidity. While the recurrence rate is significant, the morbidity of that recurrence and a redo laparoscopic fundoplication are minimal in the majority of these cases and should not be considered reasons to avoid fundoplication in appropriate patients.

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Laparoscopic treatment of benign gastrointestinal disease in children

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INTRODUCTION

With the advent of laparoscopy in the 1980s, pediatric surgeons have adapted basic laparoscopic principles to common pediatric surgical operations. This chapter describes the surgical approaches for three common conditions—pyloric stenosis, Meckel diverticulum (MD), and intussusception—for which a laparoscopic technique may have an advantage over the equivalent open operation.

HYPERTROPHIC PYLORIC STENOSIS

Hypertrophic pyloric stenosis (HPS) is one of the most common surgical diseases in infants. Typically manifesting during the first 6–8 weeks of life, infants present with progressive nonbloody and nonbilious emesis. Many infants with HPS are initially treated for gastroesophageal reflux disease (GERD) and commonly undergo several changes in formula or treatment with acid suppression therapy. Without correction, the infant will ultimately progress to the classical “projectile vomiting” seen in HPS.¹

Preoperative evaluation

Preoperative evaluation should start with a thorough history and physical examination to exclude other surgical causes of emesis, such as severe GERD, intestinal malrotation, or small bowel obstruction. Infants with HPS can be well appearing if they present early into the disease course. After several days of illness, most infants demonstrate projectile vomiting, weight loss, and low urine output. They can appear dehydrated with poor perfusion and skin turgor. Physical examination should

be focused on attempting to feel for the hypertrophic pylorus, classically described as an epigastric olive on abdominal examination. This finding can be difficult to appreciate in an awake infant, but examination can be aided by emptying the stomach and providing sugar water to soothe a crying baby.

Although clinical diagnosis is possible, most practitioners radiographically confirm the diagnosis. Historically, an upper gastrointestinal (UGI) series had been the study of choice to evaluate for evidence of gastric outlet obstruction. However, real-time ultrasound has replaced UGI, due to its speed and lack of radiation exposure. A pyloric muscle thickness greater than 3 mm is the most sensitive measure for pyloric stenosis. A pyloric channel length greater than 15 mm and a lack of pyloric channel opening also support the diagnosis.²

Most infants with HPS have some degree of dehydration; therefore, preoperative resuscitation is mandatory prior to operative intervention. Serum electrolytes should be checked on presentation. The classic laboratory findings in an infant with HPS are hypokalemia, hypochloremia, and metabolic alkalosis. The patient should receive an intravenous fluid resuscitation with a bolus of 10–20 mL/kg normal saline until there is evidence of adequate urine output. Continuous intravenous fluids should be initiated at a rate of 150% maintenance with 5% Dextrose 0.5% normal saline with 20 mEq KCl. Appropriate urine output indicates adequate rehydration for surgery. To minimize the risk of postoperative apnea, infants with severe electrolyte abnormalities should have repeat laboratory studies to confirm normalization prior to induction of anesthesia.

Operative technique

After induction of general endotracheal anesthesia, the infant is either moved to the foot of the bed or rotated

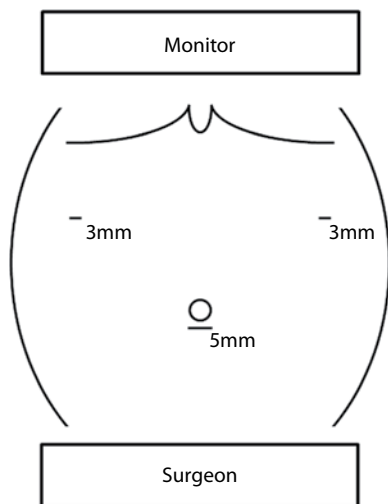


Figure 115.1 For a laparoscopic pyloromyotomy, the infant is placed supine on the operating table. The surgeon stands at the patient's feet with the monitor placed above the patient's head. A 5 mm umbilical trocar is used for the camera, and 2–3 mm stab incisions are used for the left and right hands.

transversely. Perioperative antibiotic prophylaxis is not indicated for this procedure. A 10-French Replogle orogastric tube is placed to decompress the stomach and to provide gastric distension at the end of the procedure. The operating surgeon stands at the patient's feet with the assistant to the left side. The monitor is placed in front of the operating surgeon (**Figure 115.1**). A Veress needle is inserted either transumbilically or through a 5 mm infra-umbilical incision. Care must be taken to ensure the needle is in the peritoneal cavity and not the preperitoneal space or the umbilical vein. Intra-abdominal insufflation is established with 10–12 mm Hg CO₂, and a 5 mm trocar is then placed. The patient is placed in a reversed Trendelenburg position. Using a #11 blade, two stab incisions are made in the right and left upper quadrants. After identification and stabilization of the pylorus with the left hand, an incision is made on the anterior surface of the pylorus from the vein of Mayo onto the antrum of the stomach. This incision can be made with continuous low-voltage monopolar electro-surgical energy, a Beaver blade, or an arthroscopy knife. The incision should be carried through the serosal surface of the pylorus. A closed blade, flat monopolar tip, or single arm of a laparoscopic pyloric spreader can be inserted into the muscle in the middle of and parallel to the incision, and it is rotated 90° to start the myotomy. A laparoscopic pyloric spreader is inserted in the same location, and the myotomy is extended both proximally onto the antrum of the stomach and distally to the junction of the pylorus and duodenum (**Figure 115.2**). Care should be taken to perform a complete myotomy without damaging the mucosa, which tends to bulge after the myotomy. Most incomplete myotomies will occur on the antral side of the pylorus, while most perforations occur at the pyloroduodenal junction.

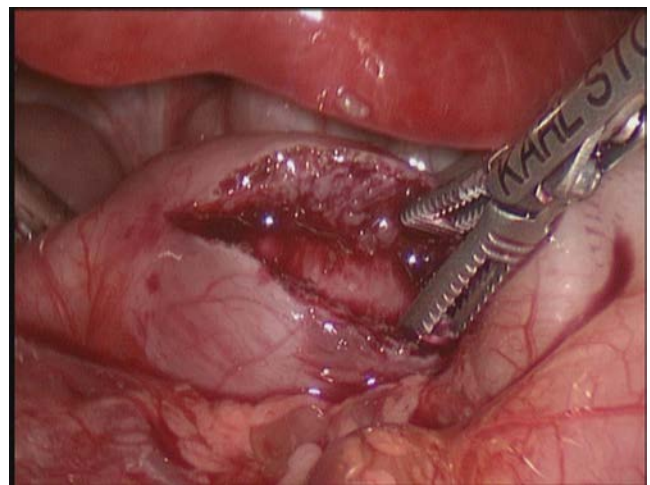


Figure 115.2 Completed pyloromyotomy.

Two blunt graspers are used to demonstrate independent movement of both sides of the myotomy. With the duodenum occluded, the stomach is then distended with 60 mL of air, and the myotomy is inspected for evidence of a mucosal perforation. The duodenum is then released, and air should be observed passing through the pylorus into the duodenum. Omentum can be placed over the myotomy if preferred. The instruments are removed, and air is evacuated from the peritoneum. The umbilical fascia and skin incision are closed with absorbable sutures.

Postoperative care and outcomes

Postoperatively, the patient is monitored for apnea for 24 hours. A variety of feeding methodologies have been described for postoperative management of pyloric stenosis. These protocols vary from *ad libitum* feeding to protocolized advancement of feedings starting with Pedialyte. Several studies have shown *ad libitum* feedings allow for a faster return to goal feedings; however, the hospital length of stay is essentially unchanged.³ Parents should be counseled preoperatively that postoperative emesis is expected after pyloromyotomy, while the gastric dysmotility is improving. Patients are discharged after tolerating feeds and a period of apnea observation.

Multiple studies have shown equivalent outcomes of laparoscopic and open pyloromyotomy. The most recent meta-analyses of four randomized controlled trials included 502 patients and compared laparoscopic to open pyloromyotomy. Laparoscopic pyloromyotomy was associated with a statistically shorter time to full feeds, with a mean difference of 2.3 hours. In addition, hospital length of stay was also significantly shorter for laparoscopic pyloromyotomy with a mean difference of 2.4 hours. While these differences are statistically significant, the clinical relevance is not well defined.⁴ The laparoscopic approach was not associated with a significantly increased risk of immediate complications, such as perforation or incomplete myotomy.

MECKEL DIVERTICULUM

Meckel diverticulum (MD) is one of the most common congenital anomalies of the gastrointestinal tract occurring in between 1.5%–3% of the population. The embryologic origin of an MD is as an omphalomesenteric duct remnant as the fetal intestines become separated from the yolk sac during embryogenesis. Failure of the ductal remnant to obliterate between the fifth and seventh weeks of gestation leads to the development of an MD. The MD may contain two types of ectopic mucosa, gastric or pancreatic, leading to variability in the clinical presentation.⁵

Preoperative evaluation

MD can present with perforation, small bowel obstruction, or gastrointestinal hemorrhage. Patients with a perforation typically demonstrate focal or generalized peritonitis. In the absence of free peritoneal air, these patients are frequently misdiagnosed with acute appendicitis, since the pain can be localized in the right lower quadrant of the abdomen. Imaging studies such as ultrasound or computed tomography may show inflammatory changes in the right lower quadrant with a normal appendix. Occasionally, a thickened bowel loop can be suggestive of an MD, but this finding is not necessarily diagnostic.⁶

MD can cause intestinal obstruction from intussusception, volvulus, or twisting around a mesenteric band. Patients presenting with bilious emesis, abdominal distention, and evidence of small bowel obstruction on abdominal radiographs in the absence of any surgical history or hernias on examination should raise the suspicion of an MD. No further imaging is usually required, and diagnosis is made at the time of exploration.

Patients with gastrointestinal hemorrhage attributable to an MD are typically under the age of 2 years and have a history of painless bright red blood per rectum. A physical examination will exclude any anal pathology as the cause of the bleeding. A technetium-99m pertechnetate radionuclide study ("Meckel scan") is commonly used to identify an MD. The radiotracer is taken up by gastric mucosal cells and excreted into the gastrointestinal tract, and thus detects the presence of heterotopic gastric mucosa within the MD. Even in experienced hands, this study has a sensitivity of 60%–80% and a high false-negative rate.⁶ The study can be improved with administration of an H₂-blocker or pentagastrin to increase radiotracer uptake in gastric mucosa.

Operative technique

After induction of general endotracheal anesthesia, the child's abdomen is prepped from nipples to pubis. Perioperative antibiotic prophylaxis covering enteric flora is administered. Both the operating surgeon and the assistant stand on the patient's left side. The monitor

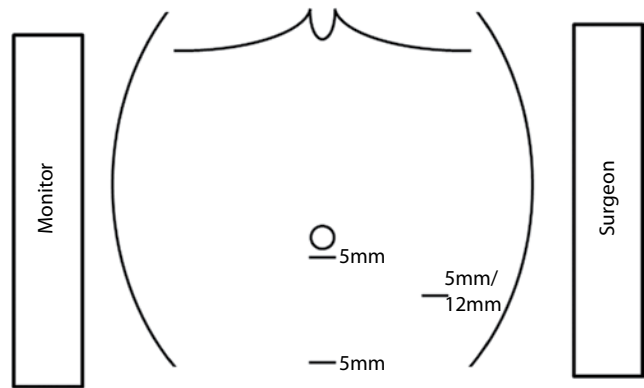


Figure 115.3 For a laparoscopic Meckel diverticulectomy or intussusception reduction, the patient is placed supine on the operating table. The surgeon stands on the patient's left side with the monitor placed on the patient's right side. A 5 mm umbilical trocar is used for the camera, and two 5 mm trocars in the left lower quadrant, midclavicular line, and suprapubic midline are used for the left and right hands. If a diverticulectomy is performed, the left lower quadrant trocar can be enlarged to a 12 mm to accommodate a laparoscopic stapler.

is placed above the patient's right side (Figure 115.3). A Veress needle is inserted either through the umbilicus or a 5 mm infraumbilical incision. Intra-abdominal insufflation is established with 10–12 mm Hg CO₂. A 5 mm trocar is then placed through the umbilical incision. Two working 5 mm trocars are placed in the left lower quadrant at the midclavicular line and suprapubic region. Abdominal exploration is started by identifying the presence of and lysing any omphalomesenteric bands. Subsequently, the cecum, appendix, and distal small bowel are examined for any evidence of intussusception, which should be reduced. The terminal ileum is then identified, and the small intestine is examined in a retrograde fashion. MD will usually occur within 2 feet of the ileocecal valve, but the entire small intestine should be examined to the ligament of Treitz (Figure 115.4).

Once MD is identified, a determination should be made to perform either a diverticulectomy or a formal small bowel resection. In patients with obstruction or perforation, a simple diverticulectomy may be sufficient. In the patient with gastrointestinal hemorrhage, a formal small bowel resection may be the safest option as ulceration on the mesenteric border of the intestine may preclude a diverticulectomy.⁷

To perform a diverticulectomy, the left lower quadrant port is enlarged to 12 mm to accommodate a laparoscopic stapling device. The base of the diverticulum is inserted into the stapler in a transverse fashion across the small intestine to avoid narrowing the intestinal lumen. One firing is usually sufficient to remove the diverticulum. Any feeding vessels should be identified and clipped to ensure hemostasis. The staple line is inspected for hemostasis, and pneumoperitoneum is evacuated. The fascia and skin are closed with absorbable sutures. Some surgeons will perform

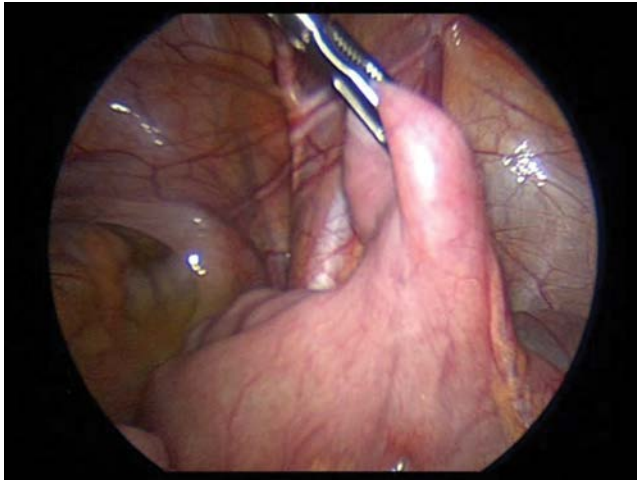


Figure 115.4 Meckel diverticulum.

extracorporeal diverticulectomy if the diverticulum can be easily delivered through an umbilical incision.

Small bowel resection is best performed extracorporeally. The umbilical incision is enlarged to deliver the diverticulum and accompanying small intestine out of the abdominal cavity. The authors prefer a hand-sewn end-to-end anastomosis; however, a stapled anastomosis can be performed in an adolescent.

Postoperative care

Postoperatively, these patients tend to recover bowel function rather rapidly. Most patients who had a diverticulectomy can be advanced to a regular diet within 24 hours. Hospital discharge usually occurs within 1–2 days. For patients undergoing a small bowel resection, intestinal function return may be more delayed. In current series, the morbidity rate for a diverticulectomy is low (1%–2%) with extremely rare mortality.⁸

INTUSSUSCEPTION

Intussusception occurs in approximately 1 in 2,000 children, the majority under 3 years of age. Intussusception develops when proximal bowel (intussusceptum) invaginates into a distal segment (intussusciens). This process occludes the mesenteric vessels of the intussusceptum causing edema and venous congestion, which will progress to gangrene and necrosis. Intussusceptions vary by anatomic location and may be jejunoileal, ileoileal, ileocolic, and ileo-ileocolic. The underlying cause of the intussusception in 90% of children's cases is idiopathic; however, 10% will have an underlying lead point, such as an MD, appendix, polyps, lymphoma, or foreign body. Older patient age (>5 years) should prompt a search for a pathologic lead point.⁹

Preoperative evaluation

Regardless of the underlying cause and location, the majority of intussusceptions have a similar presentation. Classic symptoms of abdominal pain, emesis, and rectal bleeding in a child of the appropriate age are almost diagnostic of intussusception. Stools are typically described as “currant jelly.” Unfortunately, these only occur in 25%–50% of patients.⁵ Other presenting findings vary from minor symptoms such as fever, diarrhea, and constipation to life-threatening peritonitis and septic shock.

Laboratory values are mainly used to assess the severity of the patient's illness. Imaging remains the mainstay of diagnosis in intussusception. Plain abdominal radiographs are generally nonspecific, although some may show an obstructive picture or soft tissue density in the right upper quadrant. Ultrasound (US) is the most common modality for diagnosis of intussusception in pediatric centers. In experienced hands, US has sensitivity and specificity approaching 98%.¹⁰ Classically a “target sign” is identified. US can also assess blood flow to the intussusceptum, identify any intramural gas, and demonstrate a pathologic lead point. Computed tomography and magnetic resonance imaging have little utility in diagnosis of intussusception but may be helpful in the search for a pathologic lead point.

Operative technique

In the absence of hemodynamic instability or peritonitis, the first treatment of intussusception is a contrast enema, either under continuous fluoroscopy or ultrasound guidance. Traditionally performed with barium or Gastrografin, the majority of centers now perform pneumatic contrast enemas. Success rates for radiologic reduction have approached 80%–95% in the recent literature.⁵ Risk factors for failure of radiologic reduction include young (<6 months) and older children (>5 years), longer duration of symptoms (>72 hours), or severe rectal bleeding. These factors should not preclude an attempt at reduction in an appropriately resuscitated child. Repeated attempts at reduction are indicated in patients with recurrence of intussusception after successful radiologic reduction or after partial but not complete reduction at the initial attempt. The child must remain in stable condition without signs of intestinal compromise or perforation.

Operative intervention is reserved for children with hemodynamic instability, peritonitis, or failure of radiologic reduction. Reduction can be approached through either an open or laparoscopic approach. The laparoscopic setup is similar to an appendectomy or Meckel diverticulectomy with three 5 mm trocars (**Figure 115.3**). Antibiotics to cover enteric organisms should be administered. Abdominal exploration is started by identifying intussusceptum, typically in the right lower quadrant. Using gentle traction on the intussusceptum while maintaining pressure in the intussusciens, the intussusception is reduced. After reduction, the bowel should be

examined from the cecum proximally looking to identify any pathologic lead point and assess viability. If the presence of ischemia or necrosis is identified, a small bowel resection should be performed, either intra- or extracorporeally.

Postoperative care

Postoperatively, these patients tend to recover bowel function rather rapidly, especially if a bowel resection was not performed. Diets can be advanced within 24 hours. Hospital discharge usually occurs within 1–2 days. For patients undergoing a small bowel resection, intestinal function return may be more delayed. Laparoscopic reduction of intussusception has been shown to have a significant decrease in hospital length of stay without an increase in complications.¹¹

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Image guided surgery



Edvard Munch, *On the Operating Table*, 1902–03. Oil on canvas, 43 × 58 1/2 inches. Munch Museum, Oslo.
(Artwork in the public domain; image © Munch Museum.)

This work was completed during a particularly tumultuous time in the life of Edvard Munch, the famed painter of *The Scream* (1893). Several years after completing his iconic work, in 1898, Munch entered into a dramatic love affair with the daughter of a wealthy wine merchant in Kristiania (today Oslo) named Tulla Larsen. Their passionate union is detailed in a series of intimate portraits by Munch and their extensive correspondence details travels to Berlin and

Paris, as well as an extended separation because Munch contracted an illness and went to a sanatorium. When Tulla announced their engagement without consulting Munch, he called off the relationship, prompting Tulla to go to even more extreme measures to win her lover's attention. This culminated in 1902 with her failed suicide attempt and, in September of that year, a pistol shot that damaged Munch's middle finger. Although the circumstances of the shooting

remain a mystery, scholars are fairly certain that it was accidentally self-inflicted—the result of a heated argument. The following day, Munch underwent surgery to remove the bullet in his hand at the Rikshospitalet (Oslo National Hospital).

The Operating Table is based on this experience, which also included an X-ray, a recent discovery by the German physicist Wilhelm Röntgen (who won the Nobel Prize for his invention in 1901). Munch is said to have been fascinated by the X-ray's ability to visualize grains of wood, which he later used as inspiration for his art. In this painting, however, Munch has depicted himself nude on the operating

table, surrounded by a small group of faceless surgeons and a nurse who carries a bowl of what appears to be the artist's blood. Seen from an oblique angle, the artist's body shows no signs of trauma despite the blood-stained sheet beneath him. Nonetheless, the minor wound seems to have attracted a large crowd of onlookers in the operating theater. By depicting an audience in the painting, the artist also implicates us, the viewers of the painting, as witnesses of the procedure. Medical themes appear frequently in Munch's work, perhaps owing to the fact that his father was a military surgeon and his mother and sister both died of tuberculosis when he was young.

Surgical procedures performed in radiology suites

KINGA A. POWERS AND KELLEY WHITMER

INTRODUCTION

Visualizing the subject field inherently defines successful surgical procedures. “Good exposure is the key to good surgery” is advice that John Bookwalter, upon inventing the Bookwalter retractor, recollected from his mentor, Cornelius Sedgwick, in the late 1970s. The concept of exposure has evolved along with technological advances in surgery. The classic image of Rembrandt’s seventeenth-century painting *The Anatomy Lesson of Dr. Nicolaes Tulp* portraying a filleted surgical field wide enough for crowds of onlookers to visualize each step of the operation is in stark contrast to the minimally invasive, laparoscopic approach used by many surgeons today: surgery via a telescopic lens projected onto multiple high-definition monitors suspended in the operating room.

As an alternate mode of enhancing exposure, it has become nearly ubiquitous to use X-ray, ultrasound, or fluoroscopy in at least some corner of a surgeon’s practice. Diagnostic imaging has concomitantly expanded into its own therapeutic field of interventional radiology. The rapidly flowing superhighways of surgery and radiology have veered from running parallel to converging, and have already demonstrated several instances of merging into a single path as evidenced by vascular surgery’s adoption of the endovascular approach and orthopedic surgery’s reliance on fluoroscopy.

SURGERY IN THE RADIOLOGY SUITE

Many minimally invasive procedures are performed in interventional radiology suites equipped with fluoroscopic, computed tomography (CT), and ultrasound imaging modalities. These procedures are often performed by trained interventional radiologists or surgeons on patients under conscious sedation or simply with local anesthesia.

Critically ill patients who are not able to tolerate a general anesthetic may benefit from these less-invasive procedures; however, appropriate monitoring devices and personnel must be available to provide required supportive therapy during the procedure. Contingency plans must include considering accessibility to an operating room, surgical instruments, and staff should the minimally invasive procedure require an urgent conversion to an open surgical intervention.

MULTIDIRECTIONAL FLUOROSCOPY: ONE PLANE OR BIPLANE

Fluoroscopic images are continuous two-dimensional (2D) X-ray projections through the body, and they appear as a movie of overlapping gray shadows of three-dimensional (3D) anatomy on a screen. A mobile, multidirectional fluoroscopy unit, otherwise known as a C-arm, can be brought into a conventional operating room. Several variations of fluoroscopic imaging exist, such as CT-fluoroscopy and cone-beam CT (CBCT) systems that can project high-resolution 3D images of organs and can be used intraoperatively.¹ Fluoroscopic guidance facilitates percutaneous procedures, such as angiography, nephrolithotomy, biliary drainage, biopsy of tissues such as lung nodules or bone lesions, or accessing subcutaneous radiopaque foreign bodies. With biplane fluoroscopy, two units are used set at 90° to one another, and they can acquire simultaneous imaging in orthogonal planes. Used in cerebral and coronary diagnostic angiography and interventions, this has been reported to reduce the total contrast load and possibly radiation dose to patients compared to single-plane imaging.²

Angiography, an X-ray examination of the arteries and veins for diagnosis and treatment purposes, is a commonly performed procedure. Angiography was enabled to be performed percutaneously by the 1953 invention of Sven

Table 116.1 Angiographic vascular procedures**Improving the lumen**

Balloon angioplasty	A complex technology that widens narrowed blood vessels, invented by Andreas Gruentzig in 1977. The balloon technology includes enhanced angioplasty balloons that not only dilate vessels but can also cut fibrotic lesions by using small longitudinal blades on the balloon surface or a metallic cage. Liquid nitrogen can also be used to inflate balloons for a different effect. In addition, balloons can be used as delivery agents for drugs or gene therapy vectors
Embolic protection devices	Devices that when inserted into the lumen of a vessel can diminish particulate embolization in such procedures as coronary saphenous vein bypass or carotid endarterectomy. There are three basic types: distal filters, distal occlusion balloons, and proximal occlusion balloons with or without flow reversal
Stenting	A small flexible tube made of a metal mesh that is used as an intravascular scaffold for the vessel lumen. Stents are either balloon-expandable (deployed by inflating an angioplasty balloon) or self-expanding (deployed by releasing a constraining mechanism). They are used to open blocked or narrowed vessels and can also be drug-eluting and combine the scaffolding properties with delivery of drugs that prevent stenosis
Stent graft	Also known as an endograft, a stent graft is a metal stent combined with a fabric material that provides a new lumen to divert blood flow. It can be inserted in a ruptured or ballooning section of an artery, prop a vessel open in occlusive disease, or redirect blood flow as in the TIPS (transjugular intrahepatic portosystemic shunt) procedure. In acute arteriovenous fistulas or pseudoaneurysms, a stent graft can be used to seal over a hole in the wall of the vessel and divert blood flow
Mechanical thrombectomy	Introducing a catheter-based device capable of pulverizing a thrombus without a thrombolytic agent, for example, using fluid jets, brushes, baskets, lasers, and ultrasound
Thrombolysis and pharmacomechanical thrombolysis	Relieves blockage by dissolving blood clots with a drip infusion or pulse-spray of thrombolytic drugs at the site of the clot in such clinical conditions as acute arterial occlusions threatening viability of an end organ, thrombotic occlusion of dialysis graft, acute thrombotic stroke, extensive deep venous thrombosis, or a massive pulmonary embolism. A mechanical thrombectomy combined with a thrombolytic agent is termed <i>pharmacomechanical thrombolysis</i>
Debulking atheroma	Technique of percutaneously removing the plaque from an artery, an alternative to surgical endarterectomy, by using a variety of biting, boring, or blasting catheter devices that are made of small blades, drills, and lasers that enable making a path no larger than the diameter of the device itself

Decreasing blood flow

Embolization	Delivery of an embolization agent such as a thrombotic gel, IVALON (a particulate embolic material), microspheres made from acrylics, hydrogels, resins, polymers, glass, foam, or steel coil or plug through a catheter to stop the blood flow to leaking blood vessels, tumors, abnormal communications between blood vessels, and abnormal blood vessels in abnormal locations. Embolization of arteriovenous malformations or life-threatening bleeding can be achieved by injecting a substance that blocks the supply of blood to the affected blood vessels. Uterine artery embolization is used to stop life-threatening postpartum bleeding or can be used to treat fibroid tumors—uterine fibroid embolization. Varicose vein treatment is also a common surgical procedure in radiology suites, where the saphenous vein is sealed through the use of a laser or radiofrequency
Endoluminal thermal or radioactive ablation	Used for obliterating the greater and lesser saphenous veins in patients with symptomatic venous insufficiency using a heat source such as a laser or a radiofrequency probe. Radioactive microspheres are used for embolization of primary and metastatic hepatic arterial lesions
Pharmacologic chemoembolization and drug delivery	Delivery of drugs or chemotherapeutic agents into an organ or tumor through a catheter when combined with an embolic agent is termed <i>chemoembolization</i> . This technique is currently being used in treating liver lesions, endocrine malignancies, and metastasis. Various liquid sclerosing or vasoconstricting agents can be used, including dehydrated alcohol

Taking things out of or through vessels

Intravascular foreign body retrieval	Use of snares, wire baskets, forceps, and grasping cones or entangling coils can be introduced through a catheter to entrap and remove a foreign object
Transvascular biopsy	Any lesion that has the potential for bleeding may be amenable to transvascular biopsy resulting in bleeding into a blood vessel. Examples are liver or renal lesions in coagulopathic patients and intravascular lesions

(Continued)

Table 116.1 (Continued) Angiographic vascular procedures*Introducing drugs or devices*

Vena cava filter	Implanting a cage-like device to break up blood clots and prevent them from reaching the heart or the lungs to prevent a pulmonary embolism
Vertebroplasty	Delivery of “bone cement” into the vertebra to alleviate chronic pain
Pain management injections	Guided injection of anesthetic and steroid into a joint, bursa, or epidural space for management of acute or, more commonly, chronic pain

Ivar Seldinger, who used a catheter to enter the blood vessel through a skin puncture and introduced devices over a guidewire into the blood vessels, including injection of a contrast agent to make the artery or vein visible on the X-ray. With this pivotal technique, the need for open surgical exposure of blood vessels for angiography has been curtailed, and thus has begun the movement of surgical procedures from the operating room to the radiology suites. Today, virtually all minimally invasive interventional radiology procedures are performed with a variant of Seldinger’s original technique.

With angiography, the contrast injection is recorded and projected by digital subtraction angiography (DSA). The surrounding structures can be digitally subtracted from the displayed images to record only arterial passage of contrast. Today’s technology allows for 3D reconstruction of angiographic images and aids in visualization of complex anatomy during surgical procedures. To further allow 3D reconstruction, an adjunct intravascular ultrasound (IVUS) is an available technology. An ultrasound probe is placed in a vascular lumen and allows visualization of intraluminal processes and planning of interventions.

Angiographic interventions can be grouped into those that widen, improve, occlude, or deliver a substance to the lumen of blood vessels. **Table 116.1** presents an overview of the angiographic percutaneous surgical procedures performed in radiology suites today.

Fluoroscopic images are excellent at delineating contrast between bone, soft tissue organs of differing densities (heart and lungs), or foreign bodies, such as a catheter. Contrast agents can be used to aid in soft tissue differentiation during fluoroscopy. Radiology suite interventions that utilize fluoroscopy with injected contrast include biliary drainage and stenting, where a stent is visualized to open blocked ducts, and contrast material can be injected to obtain a cholangiogram and visualize drainage of bile. Percutaneous transhepatic cholangiography (PTC) with fluoroscopic guidance can be used as an adjunct to the endoscopic procedures (endoscopic retrograde cholangiopancreatography) as a technique to evaluate and stent the biliary tree. A variety of other gastrointestinal interventional procedures are performed using fluoroscopic guidance, such as gastrostomy or jejunostomy tube placement or various gastrointestinal tract stenting (esophageal, gastric outlet, and duodenal or colorectal) or access (Roux-loop access to enter excluded bile ducts for repeated interventions). Those procedures are often performed in endoscopy suites; however, they can

also be achieved using fluoroscopic guidance in radiology suites or in the operating room. Similarly, urinary tract obstruction can be treated with fluoroscopically guided nephrostomy tube placement, ureteric stent placement, or percutaneous nephrolithotomy (PCNL) to percutaneously access the kidney and dilate a tract that permits stone removal via a nephroscope.

COMPUTED TOMOGRAPHY OR COMPUTED TOMOGRAPHY FLUOROSCOPY

Since the introduction of CT-guided nerve blocks and drainages by John R. Haaga³ over 30 years ago, interventional CT-guided procedures have become routine tools for percutaneous surgical interventions done in radiology suites. When ultrasound or fluoroscopic images do not allow imaging visualization, for example, in the lung, the mediastinum, bony areas, or areas of abdomen obscured by gas, CT is used to guide biopsies, drainages, and injections of various medications, including anesthetic and steroid into joints or the epidural space for management of acute or chronic pain. In addition, CT guidance allows access for tumor ablation techniques.

Percutaneous drainage of an abscess is a very common procedure performed in radiology suites. The minimally invasive approach allows a wider patient selection in terms of comorbidities and has been recommended by the American College of Radiology since 2000 as a suitable alternative to surgical drainage of infected intra-abdominal collections in selected patients.⁴ CT-guided drainage can be performed in a variety of ways depending on the indication, including anterior and lateral abdominal wall, transenteric, transvaginal, transgluteal, and transrectal routes. Although most drainages are done to evacuate abscesses, other liquid-filled anatomy can be accessed through this approach, including bilomas, hematomas, seromas, urinomas, cysts, pseudocysts, pleural effusions/empyemas, the renal pelvis, and the urinary bladder.

With traditional CT-guided interventions, the needle passage cannot be viewed in real time, and the patient must be brought in and out of the scanner for each needle pass. In general, the procedures require diagnostic CT scans first to establish a reference grid and to guide the puncture site of the needle. Subsequently, the patient needs to be able to be positioned supine, prone, or in lateral decubitus position for the duration of the procedure. Another disadvantage is

the radiation exposure to patient and operator, especially in complex CT-guided interventions such as radiofrequency ablation.⁵

Newer technologies allow for CT “cine” imaging and dynamic visualization. Computed tomography fluoroscopy (CTF) provides real-time fluoroscopic cross-sectional view of anatomy. The main disadvantage of CTF is the increased exposure to radiation for the patient and operator. During planning prior to the CTF or a CT-guided intervention, the doses applied need to be calculated and maximums established in advance. Intraoperative CT or CTF use is still limited; however, preoperative localization techniques with coil or wire placement can assist with minimally invasive surgery. For example, CT-placed localizing coils can aid video-assisted thoracoscopy surgery of small lung nodules or partial nephrectomy of small renal cell carcinomas or suspect renal lesions.⁶

ULTRASOUND

Ultrasound (US) uses sonic waves that are reflected back by tissue as energy. Reconstructed images effectively visualize morphology, tissue stiffness, and blood flow in the anatomy examined. Ultrasound can be used for percutaneous access or intraoperatively with surgical procedures. Ultrasound is used to guide superficial biopsies or access the renal collecting system for percutaneous nephrostomy. Ultrasound is also used to assist in access for other procedures requiring catheter access to a vein or artery, which will subsequently be primarily performed utilizing multidirectional fluoroscopic guidance. New 3D transducers have become available and can be used percutaneously and also inserted into the body (transesophageal, transrectal, intravascular, or intracardiac probes). In addition, fusion of US and preoperative CT or magnetic resonance imaging (MRI) images or models, and fusion of real-time US images with direct human vision have been developed.⁷

MAGNETIC RESONANCE IMAGING

Since its development in the 1970s, MRI has been used as an imaging tool for diagnosis and later for intervention. Initially, MRI-guided procedures were limited to aspiration and biopsies. Today the MRI-guided interventions include periradicular therapy, drainages, vascular interventions, and ablative therapies for tumors.

MRI is based on energy captured from the excitation of various tissues' hydrogen atoms with a series of magnetic fields. There is no ionizing radiation. Other important advantages include superior visualization of the organ anatomy and vasculature without instilled contrast, and multiplanar imaging with 3D capability. Furthermore, flow, diffusion, perfusion, and temperature can be measured using this modality.⁸ One limitation of MRI-guided procedures is their requirement for a unique environment

that considers safety concerns raised by the high magnetic fields. Patient monitoring equipment and instruments must be MR-compatible, and standard operating room equipment cannot be utilized. Intraoperative MRI suites are built as MR-compatible multiroom facilities with integration of other devices, such as fluoroscopy into XMR (combined X-ray and MR imaging) suites for cardiac interventions.

MIXED-REALITY ENVIRONMENTS

Multimodal imaging or augmenting the image display by combining data from various modalities like CT and MRI or fluoroscopy and CT into a single image is a rapidly advancing field of radiology.^{7,9} A drive to enhance the physical human capabilities of surgeons, including the introduction of enhanced digital intelligence to surgeon tools, is evident in the development of operating room environments where the traditional radiology, endoscopy, and surgery techniques can be used in concert. The drive to enhance human intelligence and the senses of touch, vision, hearing, and perhaps to some degree taste and smell is beginning to change the way surgeons make decisions and how they execute their function.

Current robotic-assisted surgery (RAS) technology is a very good example of this transformation, especially in the disciplines of urology and gynecology, where operations have been completely transformed. The emergence of mixed environments that allow for information connectivity, combine imaging technologies, and the use of “smart” technologies with enhanced surgical tools make the surgeon akin to a conductor directing an orchestra for the purpose of producing a beautiful musical piece—in this case, a perfectly performed operation with added value to the patient.

Real-time assistive guidance with virtual 3D imaging and image fusion to reconstruct and display pathological and normal tissue are examples of currently available advances in surgery.¹⁰ Augmented reality (AR) techniques are emerging, which are designed to enhance and augment the visualization of anatomy, especially hidden anatomy, for surgeons operating with minimally invasive techniques.⁷

RESUSCITATION WITH ANGIOGRAPHY, PERCUTANEOUS TECHNIQUES, AND OPERATIVE REPAIR

Untreated hemorrhage leads to exsanguination and death in the setting of trauma. Open approaches eliminate the natural tamponade effect of surrounding tissues and can increase hemorrhage. For this reason, hemorrhage is now treated by endovascular techniques in many cases. These procedures are normally performed by an interventional radiologist or vascular surgeon in a suite dedicated to endovascular treatment.

Treatment may necessitate transfer of a potentially unstable trauma victim from the trauma center to the

interventional radiology department, and then often to a traditional operating room for additional treatment. These transfers cost valuable time and ultimately may lead to worse outcomes or death of trauma patients. Also, endovascular suites may not be equipped to readily handle monitoring or active treatment of other life-threatening injuries during the endovascular intervention. This is being addressed through several ways summarized by the acronym, RAPTOR—resuscitation with angiography, percutaneous techniques, and operative repair.¹¹

First, surgeons are now being cross-trained by interventional radiologists during their residencies to increase their skills with endovascular techniques. Trauma patients are typically first evaluated by a trauma team who must be well versed in what technique will best treat a particular injury, be it catheter-directed embolization, endovascular repair and stent grafting, or open repair. Additionally, trauma centers are addressing the problematic transfers by equipping hybrid treatment operating rooms equipped for endovascular techniques and open repair.¹² These hybrid operating rooms may be equipped with large monitors that can display the patient's initial diagnostic CT exam, a vascular "road map" created by digital subtraction angiography, and the real-time fluoroscopic images from the endovascular treatment being administered. Following endovascular intervention, or at times perhaps during endovascular treatment of an injury, other injuries can be treated as needed by open or other minimally invasive techniques.

Obviously, the biggest limitation to this approach is the expense of building and equipping a hybrid treatment operating room and staffing this facility with appropriate specialists. An additional limitation includes surgeon training. Also, if multiple trauma victims arrive at a trauma center simultaneously, a situation that is unfortunately very common, a center with only one hybrid treatment operating room will need to appropriately triage these patients to make the best use of the available facility and staff.¹²

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Augmented reality

MICHELE DIANA, LUC SOLER, STÉPHANE NICOLAU, AND JACQUES MARESCAUX

INTRODUCTION

Reduced depth perception and reduced tactile feedback are the main challenges introduced by the minimally invasive surgical approach. The operative field displayed on a monitor induces a loss of proprioception, which to compensate for requires extensive training. Intraoperative manual palpation can provide crucial anatomical information, which laparoscopic instruments are unable to reproduce. Computer science is producing technologies allowing for an easier adaptation to the modified depth of perception and is providing surrogate experiences of physical palpation through an artificial road map of the surgical anatomy: the concepts of virtual reality (VR) and augmented reality (AR).¹ VR and AR are the fundamental components of the emerging concept of computer-assisted surgery (CAS).²

VR medical software can extract a three-dimensional (3D) virtual clone of the patient from medical imaging (computed tomography [CT] scan or magnetic resonance imaging [MRI]). This patient-specific virtual model enhances the ability to explore the surgical anatomy and can be used literally to perform a virtual surgical exploration³ and plan digitally the most suitable approach. The superposition of the preoperative digital 3D model onto intraoperative real images gives AR, and it can provide visualization of delicate or unapparent structures of interest and crucial anatomical relationships, by a modular virtual transparency. Pioneer successful applications of AR guidance have been in neurosurgery and maxillofacial surgery.⁴ Image guidance in these surgical disciplines is made easy by the presence of osseous landmarks, which are motionless and highly contrasted. As a consequence, the virtual model results are highly congruent with the real patient, while in digestive surgery AR is greatly limited by respiratory movements and by organ manipulation and deformation. However, irrespective of the clinical application, the fundamental steps to obtain AR are the same. The process to obtain AR includes the following

steps: (1) generation of a virtual patient-specific model; (2) visualization of the model in the operative field; and (3) registration, which corresponds to the accurate overlaying of the 3D model onto the real-time images. In this chapter, we briefly describe the most relevant aspects of those steps.

STEP 1: GENERATION OF VIRTUAL PATIENT'S SPECIFIC THREE-DIMENSIONAL MODEL

The key for CAS is the patient-specific virtual model. Through interactive navigation, the operator can use the 3D models for virtual surgical exploration, which can enhance the detection of critical anatomical data.³ Furthermore, the surgical approach can be safely simulated before the procedure on the real patient, and finally, the model can be displayed in real time in the operating room to guide the procedure. There are two different approaches to obtain a virtual 3D model from DICOM (Digital Imaging and Communication in Medicine) data: direct volume rendering (DVR) and surface rendering (SR) (**Figure 117.1**). DVR methods generate images of a 3D volumetric data set without delineating structures. Each gray level of the primitive DICOM image can be associated with a color and a degree of transparency through a transfer function. During rendering, a light ray going through each voxel of the 3D image is simulated, and the optical properties are cumulated along each viewing ray to form an image of the data. DVR is available on standard radiologic workstations and does not require preprocessing. DVR is also available on personal computers through open-source software, e.g., OsiriX on MacOS.⁵ Our group has developed open-source software VR RENDER,¹ which runs on all operating systems (Windows, MacOS, and Linux). DVR may enhance the understanding of anatomy, but DVR models are not adapted to computer-assisted surgery since the 3D volume is computed integrally and the different organs cannot be “virtually manipulated” separately. To fulfill the requirements for

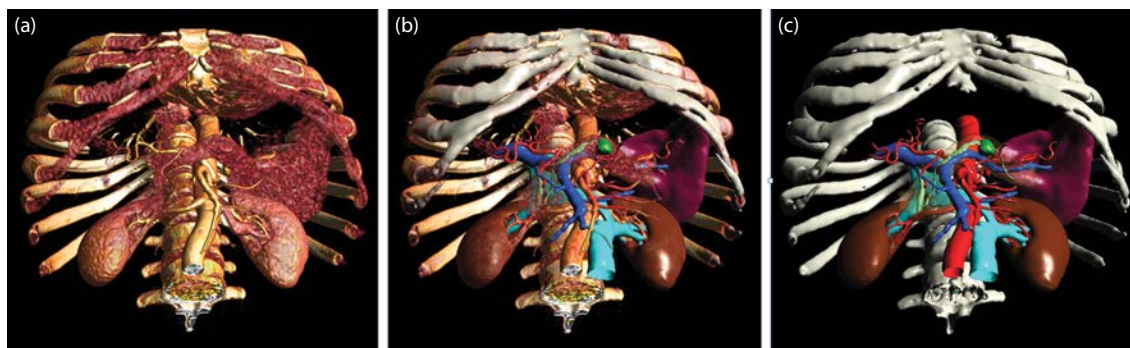


Figure 117.1 3D virtual patient-specific modeling: (a) direct volume rendering (DVR), (b) surface rendering (SR), and (c) fusion of both DVR and SR from a DICOM image.

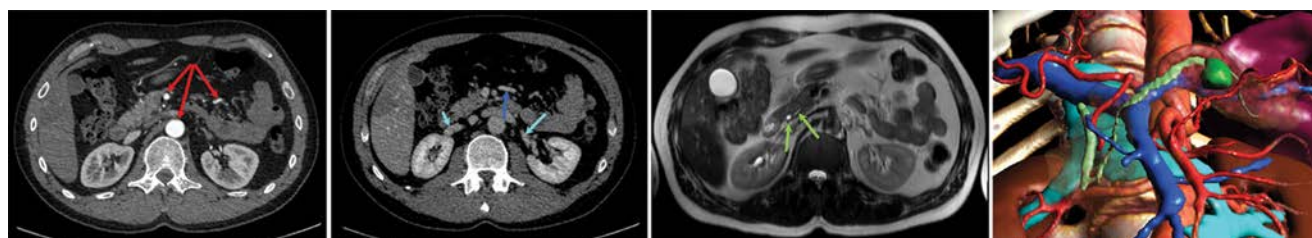


Figure 117.2 VR-Med software allowing simultaneous display and merging of different imaging modalities. CT-MRI image fusion of arteries (red arrows) segmented from the CT arterial phase; veins (blue arrows) from the CT venous phase; Wirsung and common bile duct (green arrows) from the cholangio-MRI in a single 3D virtual patient modeling.

computer-assisted surgery, 3D models should be obtained through SR. SR requires a preprocessing of organ segmentation, which can be manual, semiautomatic, or fully automatic. Based on this delineation, a colored geometrical mesh is generated automatically, and SR allows visualization of the different organs with or without transparency. SR allows modular “manipulation” of single organs, and for this reason can be used for virtual navigation, tool positioning, volumetric analysis, and organ resection planning through software such as VP-Planning. Another improvement is brought by the Visible Patient service (www.visiblepatient.com), which allows for a combination of image display and registration. For example, CT scan arterial and venous phases can be displayed simultaneously with a cholangio-MRI from the same patient, and the 3D model can be merged to have all the data of vascular and biliary tree in the same image. This fusion can be of particular interest in hepatobiliary cases (cholangiocarcinoma or pancreatic cancer), where improved planning might radically influence the surgical strategy (**Figure 117.2**).

Such 3D modeling has been used by our surgical team on more than 2,000 clinical cases for the thoracoabdominal area during the last 10 years. Recently, we could demonstrate the accuracy of the 3D Virtual Surgical Planning software (**Figure 117.3**) in determining the total liver and future remnant liver volumes in a series of 43 patients undergoing major hepatectomies.⁶

STEP 2: DISPLAY OF THE MODEL IN OPERATIVE ROOM SETTING

The next step is to display the 3D virtual model in the operative field and superimpose it onto real-time images to obtain AR during the therapeutic act. There are mainly three options.

Direct projection

A beamer is positioned above the patient, and the virtual model is projected onto the patient's skin. The visual effect is remarkable, offering a virtual transparency of the patient. We have used this method to optimize port positioning, particularly in case of robotic surgery.⁷ Similarly, Sugimoto et al.⁸ used projector-based and video-based AR navigation by overlaying DVR 3D models obtained with OsiriX 3D viewer (Pixmeo, Geneva, Switzerland) on the patient's skin and on screen to guide the placement of operative ports in laparoscopic gastric and colorectal surgeries. However, in projector-based AR, there are different perspectives, and the head positions of all of the operators should be tracked to increase accuracy, which is quite complex.

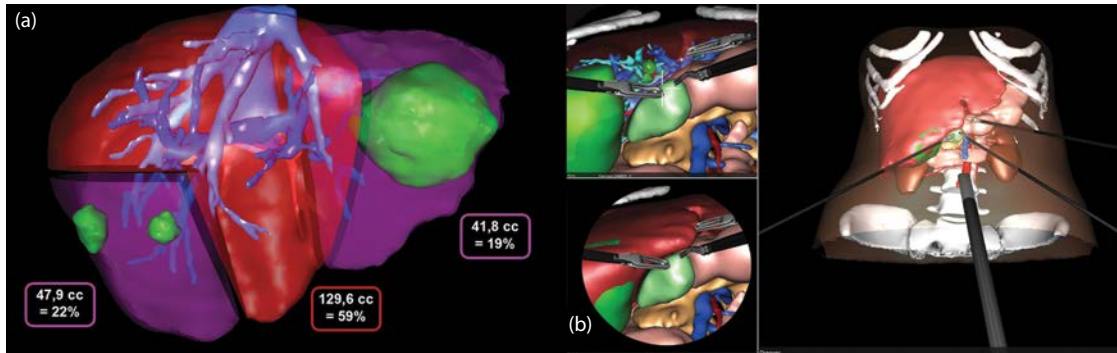


Figure 117.3 Automatic resection volume computing, virtual surgical tool positioning, and virtual planning: (a) virtual hepatic multiresection planning with remnant liver computation on the 3D model and (b) laparoscopic tool positioning and virtual surgical resection simulation.

See-through optical display

See-through display is a fascinating AR modality. A semi-transparent mirror allows the operator to integrate AR data while directly looking at the patient.⁹ Alternative see-through modality includes a videography screen with microlenses providing a 3D effect and enhanced depth perception.¹⁰ Additionally, see-through eyewear for multimedia or military applications (e.g., Google Glass, Optinvent ORA-1, Vuzix, or Laster Technologies smart vision system) can also be used to display AR. However, AR based on informative glasses needs precise tracking of pupil movements, and the current technology still does not ensure the degree of accuracy needed for surgery. Okamoto et al.¹¹ evaluated a video see-through system in three hepatobiliary cases in which the synthetic SR images reconstructed by preoperative CT scan were superimposed on real organs. Significant accuracy errors and lack of depth feedback were reported with this configuration.

Video camera display

In video camera display, the virtual 3D model is overlaid with images from the operative field, which are acquired by endoscopic or external cameras, and merged. AR is displayed directly on the screen. For an external view of a patient's internal structures, AR can be obtained through static or head-mounted cameras. The head-mounted cameras have the advantage of enabling AR in correspondence with the surgeon's sight. However, its use is limited by the needs of head position tracking and by some uncomfortable feeling for the user. In the setting of minimally invasive surgery, it is straightforward to display AR information directly on the endoscopic image as we have illustrated with adrenal surgery,¹² liver⁷ and pancreatic tumor resections,^{13,14} and minimally invasive parathyroidectomy.^{3,15}

STEP 3: REGISTRATION OF THE THREE-DIMENSIONAL MODEL

Registration is the process of accurately overlaying the 3D virtual model onto the patient's real anatomy, which is of primary importance for any AR process to be reliable. Registration is most commonly performed interactively, involving some degree of human manipulation.

A straightforward interactive registration method consists of visualizing the preoperative 3D model on the operative monitor and manually resizing and orienting the model according to some visible landmarks (e.g., bone structures such as the iliac crest or eventually some radiopaque markers used during acquisition of both preoperative and intraoperative images).^{7,12} Alternatively, the positions of landmarks can be predetermined using preoperative imaging, and during the procedure a navigation pointer again outlines the landmarks,¹⁶ and then the model is semiautomatically repositioned. When it comes to automatic registration, the main challenge of AR in soft tissue surgeries includes organ deformation or displacement by surgical manipulation or during breathing. Automatic registration is an area of ongoing experimental research and requires a lot of improvement. The key process to obtain fully automatic registration is in the ability to proceed with a real-time intraoperative update of the 3D model, or to predict the motion range with acceptable approximation. Furthermore, camera and tool calibration using fiducials and tracking systems, generally based on optical systems integrating infrared cameras and/or electromagnetic (EM) systems, are also required to compute positioning during surgery.

The main approach is to directly acquire a 3D image of the surgical field and to update the imaging at any time during surgery. This can be done using 3D ultrasound,¹⁷ as recently demonstrated by Nam et al. for liver surgery applications. Alternatively, we have proposed use of an intraoperative low-dose 3D x-ray imaging system (Artis zeego by Siemens Healthcare) to compute the new liver

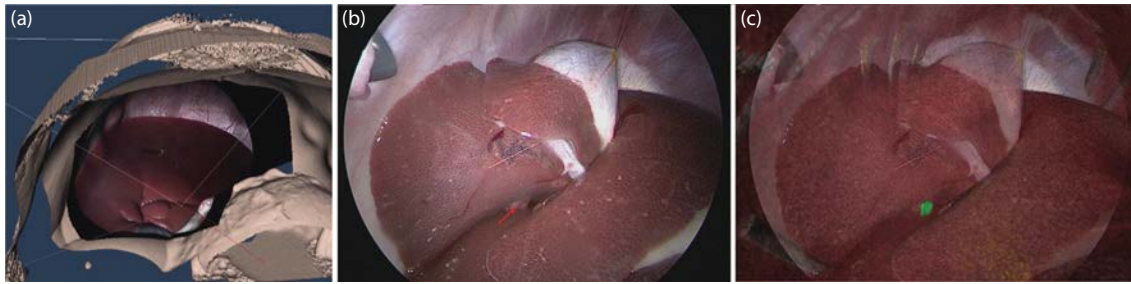


Figure 117.4 Automatic AR obtained with DynaCT image: (a) registration of a laparoscopic and a DynaCT image allowing to (b) localize and overlay precisely the tumor location (in green: adenoma chemically induced in a porcine model), even after a large liver lobe displacement (c).

shape and position and provide an up to 1 mm accurate AR view during surgical manipulation¹⁸ (**Figure 117.4**). Furthermore, to compensate for real-time deformation due to organ movement and manipulations, our group is actively working on a different approach consisting of a real-time simulation of organ deformation during the operative procedure. Proof of this concept has been initially realized for abdominal organ deformation due to breathing movement with a 1 mm accuracy real-time AR.¹⁹ Application to laparoscopic surgery will require the addition of biomechanical properties to the geometrical model of organs in order to predict their behavior under a given condition.²⁰ Patient-specific biomechanical properties could be provided preoperatively by elastographic imaging system, with magnetic resonance elastography being the preferred option.

CONCLUSIONS

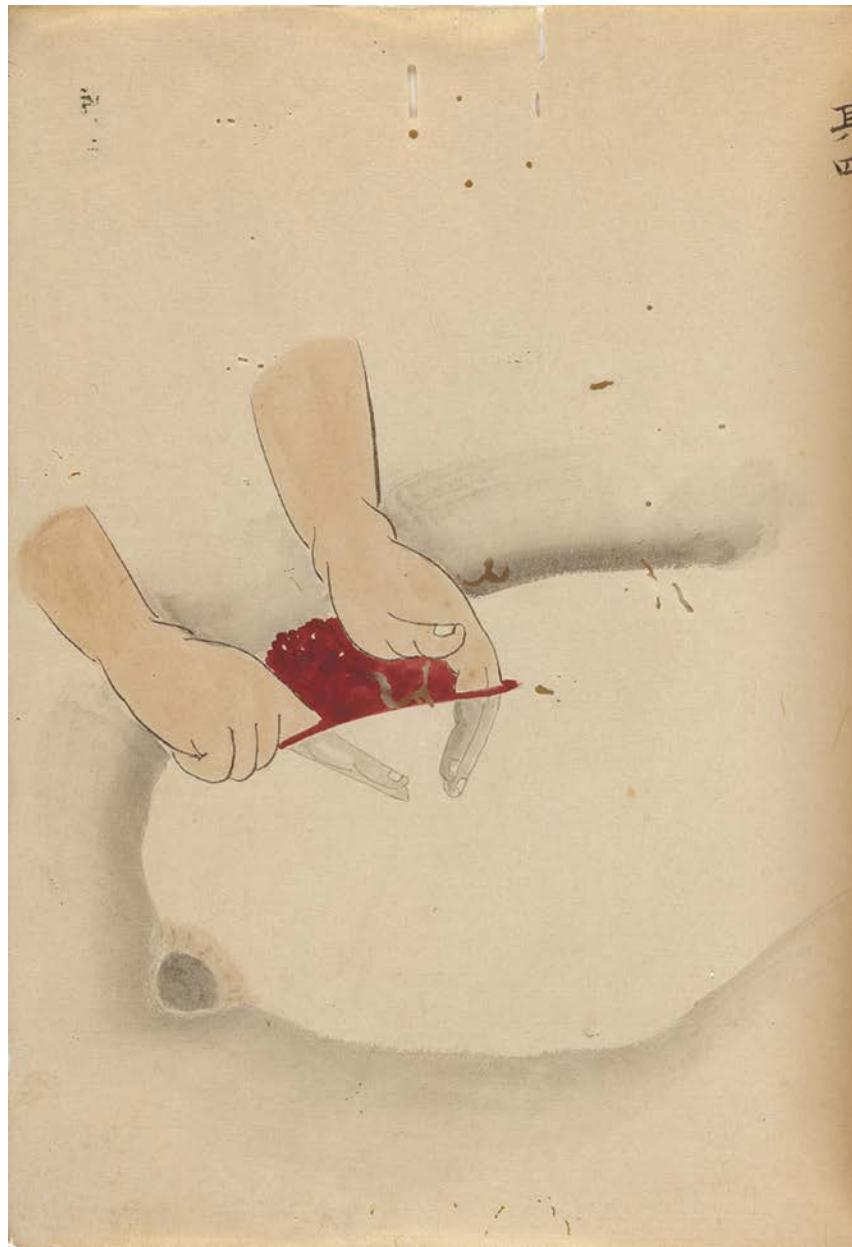
AR guidance in minimally invasive surgery is still in its infancy and poses significant challenges. However, the developments so far are encouraging. A lot is still required to provide accurate and automatic AR guidance enabling safer and easier minimally invasive surgical procedures.

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SECTION XVII

Essay on issues in minimally invasive surgery



Hanaoka Seishū, Breast cancer surgery, ca. 1800–35. Published in *Illustrated Book on External Treatments for Unusual Diseases (Kishitsu geryō zukan)* (Japan: Tangetsu, 18–?), 61. US National Library of Medicine, Bethesda, MD. (Image courtesy US National Library of Medicine.)

What was it like to perform surgery before the use of medical imaging devices? Before the invention of technology that allowed doctors to see inside of the body, surgeons often relied on written description and medical illustrations to “see” common maladies and their treatments, in addition to learning firsthand from experienced teachers. In eighteenth-century China and Japan, physicians wanting to perform surgery often used manuals to learn how to produce their own surgical instruments and perform surgical techniques. The Japanese surgeon Hanaoka Seishū (1760–1835) prepared such a book showing patients with transparent or invisible skin, so that others could view a variety of afflictions, including tumors, goiters, and burns.

This beautifully rendered image depicts Hanaoka removing a tumor from the breast of a 60-year-old woman named Kan Aiya on October 13, 1804. She was the first patient to undergo surgery using Mafutsusan, an anesthetic made from the datura flower, which is widely recognized as the first surgical procedure to be performed under anesthesia (despite later Western developments based on ether). Hanaoka performed many such surgeries and taught his

students how to perform them as well. The book shows the tools used in the procedure—a pair of scissors and a scalpel—and how they were used in the lumpectomy. After making a three-inch vertical incision above the tumor, Hanaoka felt around for the tumor with his left hand while incising it with the right, as seen in this image. The book then presents the excised tumor, complete with cross-sectional views.

This manuscript was likely prepared between 1804, when the surgery was completed, and 1835, when Hanaoka died. It was illustrated by a Chinese artist named Tangetsu, who is identified with a red stamp on the back cover. The quality of the illustrations suggests that the book was created in honor of Hanaoka’s many accomplishments, and given that his patient notes have been lost, this book is a valuable record of his cases.

Annotated guide to Hanaoka Seishū’s Surgical Casebook, National Library of Medicine, accessed 27 July 2018, <https://ceb.nlm.nih.gov/proj/ttp/flash/hanaoka/hanaoka.html>.

The challenges and solutions of performing minimally invasive surgery in underdeveloped environments

RAYMOND R. PRICE AND ADEWALE O. ADISA

INTRODUCTION

Aseptic technique, anesthesia, and minimally invasive surgery (endoscopic and laparoscopic), three patient-friendly innovations, revolutionized surgery during the twentieth century.¹⁰ Yet the benefits of minimally invasive surgery (MIS) still elude much of the developing world. Outpatient laparoscopic cholecystectomy with the ability to return to work in 4–7 days has become the standard of care in high-income countries (HICs). Unfortunately, patients in low-income countries (LICs) continue to be subjected to larger incisions, increased pain, and longer recovery—or in many instances—continued suffering for lack of any available curative treatments.

Preconceived notions about the role for surgical care—and more specifically MIS and endoscopy—in low- and middle-income countries (LMICs) have severely handicapped appropriate expansion in resource-constrained areas of the world. Many public health experts suggest that surgical care is too expensive to implement in LMICs when competing with other types of interventions to improve health. Some argue that developing laparoscopy in LMICs places additional strain on an already tenuous medical system where there are limited physical (electricity, running water, hospital infrastructure, and equipment) and human resources (absolute numbers, inadequate training, and significant learning curves for proficiency in MIS).

Many voices from the developing world provide markedly different poignant counterarguments promoting the development of more robust surgical care including MIS in LMICs. The MIS pioneer from India, Dr. Tehemton Erach Udwadia, stated, “I believe surgery is a humanitarian science, and if it is to be that, then the cutting edge of surgical progress must be made available and affordable to all people in all places.”¹⁰ Dr. Leslie Akporiaye, Medical Director of the Shawsand Medical

Center in Delta State, Nigeria, where he is developing laparoscopic surgical capability, remarked, “As we now live in a global society, it would be unconscionable for Nigerians to be denied the medical advantages of new technology.” And from the austere environment of the high steppes of Mongolia, where 33% of the population continue living a nomadic lifestyle, Dr. Orgoi Sergelen, Chief of Surgery at the Mongolian National University of Medical Sciences (MNUMS), who led the countrywide expansion of laparoscopic cholecystectomy, emphatically stated, “Laparoscopic surgery is more important for developing countries than high-income countries.”

Increasingly, the global community, understanding new possibilities for improved quality surgical care, is recognizing the benefits to the general population and to the local economies through development of minimally invasive and endoscopic surgery despite the challenges faced in resource-poor environments. The barrier to surgical care, including MIS in all its forms, may not necessarily be related to funding (or the lack thereof) but more to the lack of vision for innovative methods for implementation. If surgical care, as stated by Jim Kim, President of the World Bank, is truly an “indivisible, indispensable part of healthcare,” and since MIS and endoscopy can help millions of people lead healthier and more productive lives, then maybe one of the new frontiers for improved global health should include the worldwide expansion of MIS in resource-restricted environments.

CHALLENGES

Poverty

Poverty causes the greatest suffering on earth; it is the main reason why MIS and endoscopy are mostly unavailable in LMICs, causing patients to suffer from more painful, and often

longer, incapacitating procedures, and present with later stages of surgically treatable conditions. In many countries, MIS is limited primarily to private hospitals, possibly widening the surgical gap between the rich and the poor. Understanding the challenges facing the expansion of MIS and endoscopy worldwide can help identify appropriate solutions.

Burden of disease

Surgery has traditionally been neglected as an integral component of public health for improving the overall health of communities.⁴ The most recent report on the burden of disease indicates that an epidemiological transition of disease is occurring where chronic conditions, many surgically treatable, are now more common than the traditional infectious causes. In fact, 5 billion (not the previously reported 2 billion) people lack access to safe, affordable surgical and anesthesia care when needed.¹⁵

To address such a large burden of previously unrecognized diseases within the context of limited global resources, initiatives that provide high yield results, that can reach the entire population, and that are low cost receive the greatest endorsement. Without adequate evaluation of the cost-benefit analysis of MIS in LMICs, many have assumed that MIS and endoscopy do not have a role in global public health.

The World Bank's *Disease Control Priorities in Developing Countries* 2nd edition (DCP2) identified four distinct areas where surgery could play a role for improving global public health: Trauma, Obstetrical Emergencies, Acute Surgical Emergencies, and some Non-Acute Surgical Conditions.³ Building on this body of evidence, the *Disease Control Priorities* 3rd edition (DCP3) appropriately highlighted that essential surgical procedures rank among the most cost effective of all health interventions.^{5,6} Their list of 44 essential surgical procedures does not include laparoscopy or many other MIS procedures. The DCP3 and the World Health Assembly resolution for including essential surgery as part of universal health care recommends financing universal coverage of essential surgery first on the path to universal health coverage (Figure 118.1).

Leaving MIS out of the definition of "essential surgery" has the potential to significantly limit the expansion of MIS over the new 2015–2030 sustainable development goals (SDGs) agreed upon by the world's nations if MIS continues to be viewed as a high-cost procedure and limited to a select portion of the population.

Lack of infrastructure

Many of the early advances in endoscopy and MIS came from innovators who lived in surroundings very comparable to the developing world today. Before video laparoscopy, the Johns Hopkins Program for International Education in Gynecology and Obstetrics (JHPIEGO), with financial assistance from the Agency for International Development

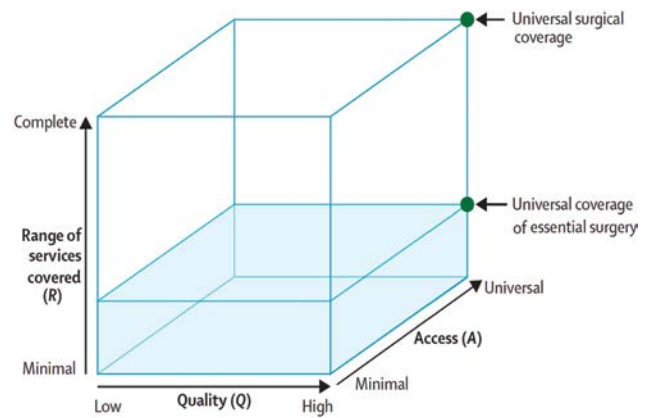


Figure 118.1 The dimensions of universal coverage of essential surgery. (Mock CN et al. Essential surgery: Key messages of this volume from *Disease Control Priorities*, World Bank, 2015; Vol. 1, p.14. http://dcp-3.org/sites/default/files/chapters/DCP3_Essential%20Surgery_Ch1.pdf)

(AID), expanded basic laparoscopy for use in gynecological diagnosis and fertility management throughout Africa, Asia, South America, and the Middle East from 1973 to 1983. They had 51 training centers in 34 different countries where they trained 2,901 physicians. A follow-up survey of the equipment installed found 90% continued usage.¹⁶

However, MIS and endoscopy gradually evolved to include more expensive equipment as the demand for video laparoscopy, and better laparoscopes, cameras, monitors, insufflators, and energy devices skyrocketed. The unstable electrical grids thwarted widespread introduction of modern video laparoscopy in LMICs. Ninety-five percent of technological equipment in LMICs has been donated from visiting surgical teams; much of the equipment has often not been designed to contribute toward long-lasting system improvements (LCoGS). A significant amount of the equipment was used or refurbished older equipment. Fifty percent of the equipment ceased functioning due to a myriad of reasons, including lack of spare parts, excess sophistication, or local personnel who did not know how to use it.¹⁷

Any form of maintenance agreements usually did not accompany most of the donated equipment.

Attempts to introduce MIS into resource-limited environments have been plagued by this phenomenon of dumping old equipment, causing many to question the sustainability of laparoscopy in LMICs. Even Mother Teresa stated, "I do not need your surplus. I do not want you to give me your leftovers. Our poor do not need your condescending attitude nor your pity." The World Health Organization developed a similar statement addressing appropriate technology in LMICs, "It is not only a waste of precious resources to move useless and unsafe equipment from one place to another, it also undermines the good will and trust that those involved are trying to build."¹⁸

Limited human resources

In many parts of the world, general doctors provide the majority of surgical care. The few certified surgeons and anesthesiologists in LMICs are found mostly in urban areas; rural areas may find only one surgeon for 2 million people. Surgical residencies are often short and do not include any specific training in MIS or endoscopy. Postgraduate continuing surgical education is usually unavailable or provided by short-term surgical missions for procedures that have a documented steep learning curve. Formal certification by governing bodies is in its early developmental stages. Some countries are actively training nonphysician providers to perform surgical procedures (abscess drainage, hernia repair, and cesarean section) to improve access to at least basic surgical care needs.⁷ This limited surgical capability makes surgery a challenge, not only for MIS, but also for even the most basic procedures.² When expertise is developed in MIS, there is a natural process to migrate to areas that provide adequate equipment and supplies to perform MIS, leading to the “brain drain” of well-trained providers from rural areas to more urban areas or even to other countries. This lack of surgical workforce and resources causes some to question whether MIS surgery is safe to develop in LMICs or if LMICs are even capable of providing care for the complications that could occur.²

Inadequate health care financing

Money alone does not necessarily lead to improved health care. While the United States spends more of its gross domestic product on health care than any other country, it ranks only 50th among 221 nations for life expectancy.¹⁹

Nevertheless, a country’s health care financing directly correlates to the volume of surgical procedures performed. The number of surgical procedures performed per 100,000 populations is extremely small for countries that spend less than US\$100/person/year compared to countries that spend more than US\$1,000/person/year¹³ (Figure 118.2).

Any type of health care, including MIS, which carries a steep price tag, will continue to provide a significant challenge to sustainable development in low-income countries. Other financial barriers to developing MIS in LMICs include local politics, tribalism, corruption, cash economies, local social philosophies, and government instability.

SOLUTIONS

Many have previously assumed that the challenges facing the expansion of MIS and endoscopy in LMICs are insurmountable. However, harnessing the time and energy previously dedicated to analyzing and predicting why MIS and endoscopy are nearly impossible in resource-restricted settings and focusing innovation toward identifying and implementing solutions to overcome these barriers might lead to new

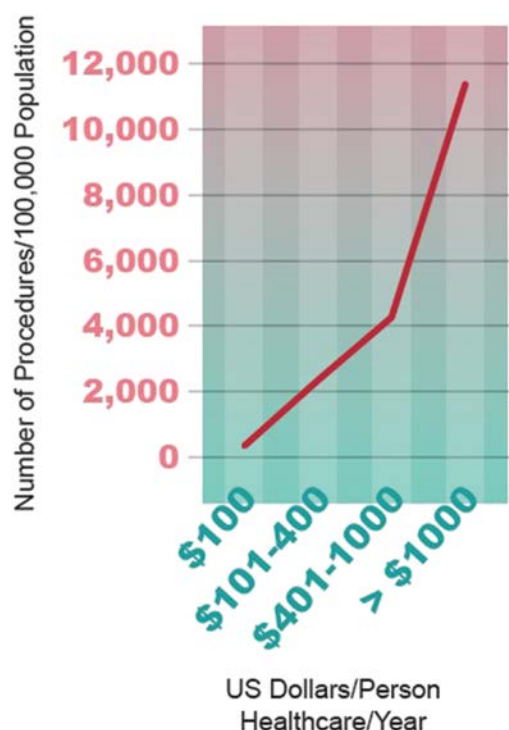


Figure 118.2 Worldwide distribution of surgical procedures (234.2 million surgical procedures worldwide). (Data from Weiser TG et al. *Lancet* 2008;372[9633]:139–44. Copyright © 2015 Intermountain Healthcare. Used with permission.)

discoveries driving the expansion of MIS and endoscopy in LMICs and secondarily improving health care overall.

Rather than being viewed as a burden to health care in LMICs, MIS and endoscopy might actually be a facilitator or enabler for strengthening health care systems (Figure 118.3).

Realization of MIS and endoscopy in LMICs will be sustainable when the local desire combines with local leadership to find the most appropriate inclusion within their

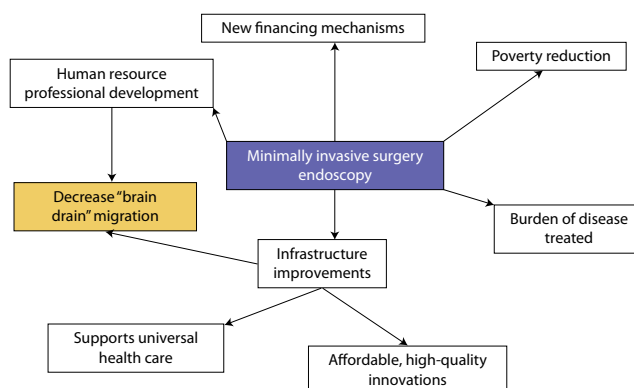


Figure 118.3 Health systems strengthening through MIS and endoscopy.

health care system. Partnerships from HICs can play a role in addressing the potential barriers, but a local champion for long-lasting change plays a central role for long-term sustainable development.

Poverty

Investing in MIS and endoscopy in LMICs may actually be a vehicle that promotes economic growth while improving the lives of a larger population. The benefit of faster recovery and earlier return to work might be more critical in the more tenuous LMICs setting, where an illness treated through MIS techniques could potentially prevent a precipitous drop in the family's economic status, for example, from a middle-income level to a low-income level.

Investing in surgical services can strengthen health care systems by providing improved earning potential through a myriad of job opportunities: Surgeon, anesthetist, nurse, scrub technician, janitor, administrator, bioengineer, and computer support are just a few of these. Quality surgery leads to the development of further expertise locally, including blood banking, pathology, and laboratory testing, which also require a better trained workforce. The overall result decreases the unemployment rate, leading to decreased poverty.

However, a recent literature review showed a complete lack of published material addressing the impact of surgery on surgical systems.⁹ The potential impact of surgery on poverty is an uncharted and important area for research that could help define the role of MIS and endoscopy in LMICs.

Burden of disease

The burden of surgically treatable diseases varies by geographic regions of the world. Gallbladder disease was the

second most common cause of inpatient morbidity in Mongolia, while it is much less common in many Sub-Saharan African nations. Beginning in 2005 in Mongolia, the Health Sciences University of Mongolia (HSUM), renamed recently the Mongolian National University Of Medical Sciences, along with the Dr. W.C. Swanson Family Foundation (SFF), and the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) initiated a countrywide campaign to expand laparoscopic cholecystectomy. This public health approach to addressing gallbladder disease in Mongolia targeted a regionally prevalent cause of morbidity with an MIS approach for the entire population. This 10-year project has seen a dramatic change in the method and geographic availability of cholecystectomy from 2% of the gallbladders removed laparoscopically in 2005, and only in the capital city, to over 65% treated regionally in the rural areas of Mongolia, in addition to increased locations in the capital city, by 2013. By 2011, the primary method for gallbladder removal transitioned from the traditional, more invasive open surgical method to laparoscopic removal. The principles leading to this successful program include understanding the needs in Mongolia, integrating modern surgical development with basic surgical techniques and principles, developing local infrastructure, enabling independent surgical growth and ingenuity, and adapting the training, infrastructure, and business models to the local environment ([Table 118.1](#)).^{8,12}

When there is a large prevalence and incidence of a certain disease in a given population (as in Mongolia), and MIS provides a dramatic improvement in patient outcomes, a case could be made that laparoscopic cholecystectomy for gallbladder disease should be included within the fourth distinct area as defined by the DCP2—Non-Acute Surgical Conditions—for improving global public health ([Figure 118.4](#)).

Where modern diagnostic capability with computed tomography and magnetic resonance imaging scanning is

Table 118.1 Principles for successful development of laparoscopic surgery in Mongolia

1. Identifying and understanding the need
 - a. Burden of disease
 - b. Professional development
 - c. Building community trust
2. Integrating modern surgical development with basic surgical techniques and principles
 - a. Developing the didactic curriculum integrating laparoscopy with basic emergency and essential surgical training
 - b. Organize high-volume practical training component
 - c. Multidisciplinary team training (surgeon, anesthetist, nurse, scrub technician, biotechnician, administrator)
 - d. Develop evaluation and research capability (quality improvement)
3. Infrastructure development
 - a. Local equipment and supplies
 - b. Sustainable local supply line and repair capabilities
4. Enabling independent growth and ingenuity within local communities
 - a. Bilateral (United States and local country) laparoscopic training teams
 - b. Incorporating laparoscopic skills labs: training the local educators
 - c. Encouraging the development of a multi-institutional training program
5. Adapting to resource-poor environment

Surgery as a public health strategy

1. Trauma
2. Obstetrical emergencies
3. Acute surgical emergencies
4. Non-acute surgical conditions

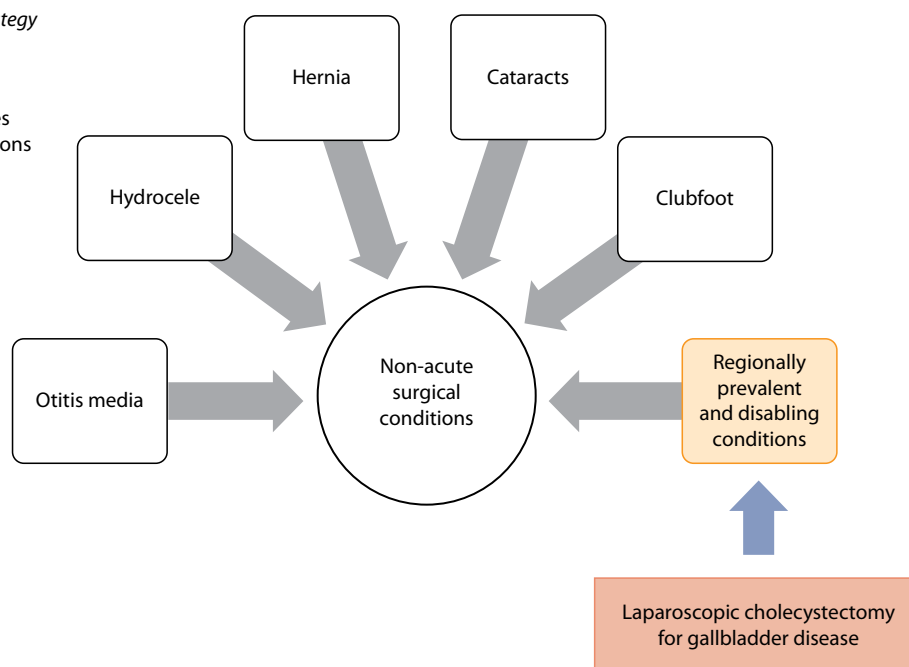


Figure 118.4 Laparoscopy as a public health strategy for gallbladder disease in Mongolia.

limited, laparoscopy for tumor diagnosis along with endoscopic evaluation for earlier detection might find a role for treating regionally prevalent and disabling conditions in Sub-Saharan Africa. MIS for obstetrics and female sterilization has already begun establishing its role for global public health in LMICs. The preventive role of MIS and endoscopy, such as colonoscopic polypectomies to prevent colon cancer or a colonoscopy and excision to prevent cervical cancer, are well documented. Further research into the ability of MIS and endoscopy to address the burden of disease as well as advocacy for MIS and endoscopy on the global stage is greatly needed.

Lack of infrastructure

Expanding surgical care in resource-poor areas, including MIS and endoscopy, is necessarily focusing innovation and technology on sustainability, including affordability, like never before. Dr. Udwardia realized early on that, “Science has no national boundaries and discounts the qualities of ingenuity and innovation which are the thrust of surgery in the developing world.”¹¹ World sentiment for equity and cost-affordable health care has led businesses, educational institutions, international funding organizations, and others to rededicate their efforts to discover innovative, extremely affordable solutions for surgical care.

Already, high-definition (HD) quality laparoscopes that are disposable but can be sterilized 25 times can be made for US\$75 are being sold with lower-cost laparoscopic light sources and cameras in India. Some HIC universities have partnered with low-income countries to design extremely affordable products that have developed into companies

supporting MIS and endoscopy. A student group from Stanford University developed a low-cost portable ventilator for US\$300 suitable for infants and adults, called “One Breath.” This won the Popular Science award in 2010. The University of Utah has projects that have led to the development of an extremely low-cost disposable HD laparoscope and insufflation machines used for laparoscopy.

The Copenhagen Consensus,¹ a meeting of leading economists (including four Nobel Prize laureates) promoted a case for the development of a broad range of surgical services beyond basic surgical services that could be highly beneficial to poor people. With the rapid development of low-cost high-quality equipment designed to work in energy-poor environments, MIS and endoscopy are likely to enter the realm of cost-effective delivery methods and revolutionize health care for LMICs as they have done in HICs. Appropriate cost-effective supply chains and long-term maintenance agreements need to accompany these products in LMICs.

Local capacity building is key for sustainable development. Models of laparoscopic missions where teams bring all the laparoscopic equipment, operate for a week or two independently, and then lock everything up until they return the following year creates more harm than good. These models undermine the trust that people place in their local surgeons, and the surgical capability disappears once good-willed donations supporting these trips wane.

Limited human resources

Physicians and nurses in LMICs want to deliver “effective preventive and curative health services to the full population,

equitably and efficiently, while protecting individuals from catastrophic health care costs,” similar to those in HICs.¹⁷ Combining infrastructure development for MIS and endoscopy with education creates an environment where health care providers at all levels develop increased job satisfaction. Investing in a well-trained surgical workforce that has the tools to deliver MIS has the potential to decrease the loss of health care providers to migration to more urban areas, or even other countries, helping to maintain the professional expertise locally. Patients develop increased trust in their surgeons when they see their family members and friends recover so quickly. MIS provides surgeons with a needed source for professional advancement and pride in the care they can deliver.

Addressing the surgical treatable burden of disease in LMICs requires investing in training an adequate well-trained workforce. A combination of designing appropriate postgraduate training as well as including MIS and endoscopic training into residency programs can help strengthen the health care system. The Lancet Commission on Global Surgery has recommended that Ministries of Health should develop surgical workforce plans to achieve surgical workforce densities of 20–40/100,000 with adequate rural and urban distribution by 2030. For MIS to deliver its full potential to improve patient lives and improve economies, training in MIS and endoscopy must be included in this worldwide initiative based on the regional difference in the burden of disease.

Inadequate health care financing

Overcoming many countries, low investment in health requires marketing the dramatic value proposition that MIS and endoscopy provide for local economies. The quicker recovery, rapid return to work, less pain, decreased scarring, and earlier diagnosis and treatment all lend evidence that surgical services in LMICs save lives and promote economic growth. Scaling up surgical services including MIS must be viewed as an investment, not a cost. It took many years of expanding laparoscopic surgery throughout Mongolia with very little investment from the Mongolian government. In 2014, outcomes research, patient and doctor interviews with local media, and widespread public demand led to the Ministry of Health agreeing to financially support laparoscopic cholecystectomy countrywide.

It is often unrecognized that acceptable, affordable surgical care requires advocacy on behalf of patients and communities. Government officials can play an important role for developing MIS and endoscopy through legislation, execution of policy, and allocation of resources for action.¹⁴

Financing MIS in LMICs includes a variety of potential sources, including private and public funding. A study by the International Finance Corporation (IFC) in 2009 noted over 60% of health care in Sub-Saharan Africa was privately funded. In fact, the private sector was often the only option for delivery of health services in remote rural regions and

poor urban slums. The 4 billion people at the lower end of the income distribution still make a formidable source for private health care enterprise that with demand could propel MIS development in LMICs. The IFC recommended improving the environment for private health care to flourish in LMICs by creating an equity investment vehicle, partnering with local financial institutions, providing advisory services to build capacity within local financial intermediaries, helping expand the education of health care workers, and encouraging the development of health insurance companies.

The Lancet Commission on Global Surgery identified potential sources for public revenue to invest in scaling up surgical care in LMICs. These included increased mobilization of domestic resources (through general taxation and taxation of tobacco and alcohol), reallocation and efficiency gains (reducing or eliminating fuel subsidies), and contributions from external resources (both traditional development assistance for health [DAH] and innovative financing). As the equity revolution continues, whereby local communities demand access to high-quality surgical care including MIS, countries will begin to support more sustainable development of MIS and endoscopy. Adequately funding the local health care providers can play a role in maintaining expertise locally.

CONCLUSIONS

While there are many challenges to MIS and endoscopy in resource-restricted areas of the world, many surgical, public health, business, and engineering innovators are challenging the prevailing thought that MIS and endoscopy are too expensive and are transforming health care for LMICs by discovering solutions to these challenges. Solutions will primarily come from leaders within these countries, at times with assistance in partnership with HIC institutions and organizations. Previously thought to be inaccessible to the billions of people in LMICs, timely and appropriate MIS and endoscopy are already building communities, expanding economies, saving lives, and engendering hope. Dr. Edgar Rodas, previous Minister of Health from Ecuador, provided great counsel to a group of medical students regarding difficult challenges, “Do not let the four walls of the operating room limit your view of the horizon of possibilities.”

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Essay: The future of robotics in minimally invasive surgery

CRYSTAL KRAUSE, SONGITA CHOUDHURY, AND DMITRY OLEJNIKOV

INTRODUCTION

As the trend in surgery moves toward less invasive procedures, there has been an increase in the use of laparoscopic and robotic surgery. While laparoscopic surgery has helped tremendously in reducing patients' scarring, morbidity, complications, and hospitalization time, it has also limited surgeon dexterity, sensory feedback, and visualization. Computer-assisted surgical robotics has addressed many of these limitations of traditional laparoscopic surgery, such as reduced visual field, stabilization of tool vibrations, reduced number of incisions, and improved surgical ergonomics for the surgeon. While there have been rapid advances and improvements in robotic systems, large gaps in the technology still exist that need to be addressed, including enhancing haptic feedback, increasing safety mechanisms, and improving range of motion of instruments. The purpose of this chapter is to review the history of computer-assisted robotics in surgery, discuss some of the currently utilized surgical robots, and explore emerging surgical robotic technologies.

HISTORY OF SURGICAL ROBOTICS

The first robots used in human surgery were adapted from industrial-use robots. The very first robotic surgery was a brain tumor biopsy performed with a PUMA (Programmable Universal Machine for Assembly; Stäubli, Switzerland) 200 robot ([Figure 119.1](#)) in 1985.^{1,2} This robot mainly served to hold a probe to improve the accuracy of brain tumor biopsies and treatments.^{2,3} The PROBOT (Prostatectomy ROBOT) was also based on the PUMA robot, was capable of autonomous surgery, and was used for

transurethral resection of the prostate. Further development of PROBOT was halted due to a lack of funding and acceptance of the autonomous nature of PROBOT by the surgical community.⁴⁻⁶ The Computer Assisted Surgical Planning and Robotics (CASPAR) robot was another autonomous, PUMA-based robot, but it was designed for total hip and knee arthroplasty and for anterior cruciate ligament (ACL) repair. CASPAR used three-dimensional (3D) computed tomography (CT) data of the tibia and femur for precise, preoperative planning. In surgery, osteal channels were created by the robot with high surgical precision, and surgery was completed using conventional techniques.⁷ CASPAR was first used in Germany in 2000 for robot-assisted knee arthroplasty, but use was discontinued in 2004, as studies showed that additional efforts associated with the robot use did not pay off in postoperative patient benefits.^{3,8}

The ZEUS Robotic Surgical System (Computer Motion, Inc., Santa Barbara, California) was designed for use in minimally invasive general surgery. The ZEUS robot had motor-driven arms with actuating graspers that were directly linked to the surgical table and graspers that were inserted into the patient through a laparoscopic port. Internal viewing was accomplished via the AESOP robotic arm (also designed by Computer Motion, Inc.), which was a voice-activated, endoscope-holding arm. With the ZEUS System, the surgeon sat at an open interface, observing a digital screen to control the system and used a microphone to control the endoscope arm. The end effectors of the ZEUS had seven degrees-of-freedom (DOF), giving significant surgical dexterity. In 2001, the ZEUS System was U.S. Food and Drug Administration (FDA)-approved, and successfully performed the first long-range, transatlantic, telemanipulated surgery.⁹ In 2003, Intuitive Surgical acquired Computer Motion, Inc., and despite its promising



Figure 119.1 PUMA 200. A small robot originally designed for manufacturing assembly and other industrial applications [43].

beginning, the ZEUS System was taken off the market in favor of development of the da Vinci Robotic System.^{6,10}

The Acrobot Sculptor (Active Constraint Robot; Stanmore Implants Worldwide Ltd.) was a robotic device designed to increase the accuracy and precision of bone

resection in orthopedic surgery. It was a semiactive robot, using CT data as input, and assisted in bone resection for unicompartmental knee arthroplasty (UKA). The Acrobot consisted of a high-speed cutter attached to a three-DOF robotic arm that sculpted away bone while actively preventing the surgeon from cutting bone outside the preoperatively defined area.^{11,12} Acrobot was first used clinically in 2001, and its accuracy was demonstrated in a clinical trial in 2004. However, Stanmore Implants was acquired by MAKO Surgical Corp. in 2013 as part of a settlement in intellectual property litigation, and further marketing of the Acrobot system in the United States was stopped.¹³

CURRENT COMPUTER-ASSISTED SURGICAL SYSTEMS

The da Vinci Surgical System was developed by Intuitive Surgical, Inc. (Sunnyvale, California) and is used in a wide variety of applications, including urologic, cardiac, thorascopic, and gynecological surgeries (Figure 119.2).¹⁴ The da Vinci system is the most used surgical robotic system in the world, with over 1.5 million procedures performed and 2,600 systems installed.^{14,15} The first da Vinci-assisted human surgery was performed in Germany in 1998.¹⁴ In 2000, the da Vinci became the first robotic surgery system approved by the FDA for general laparoscopic surgery. This system helps to overcome some of the limitations of a standard laparoscopic approach and allows precise dissection in a confined space.¹⁴ The advantages of the da Vinci compared to conventional laparoscopic surgery have spurred its use in laparoscopic radical prostatectomies, helping this platform gain widespread use and acceptance by the surgical

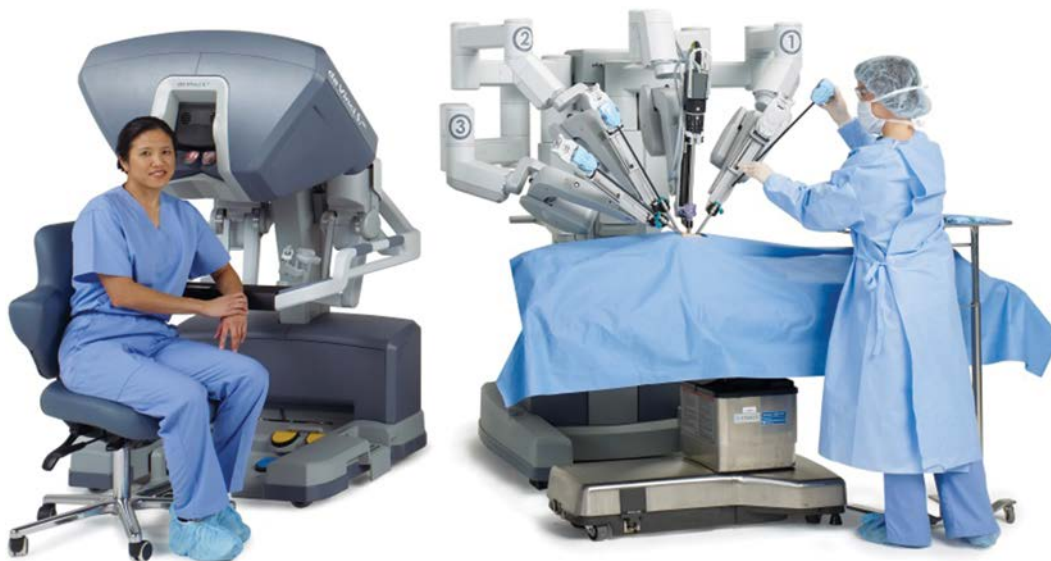


Figure 119.2 The da Vinci Robotic Surgical System consists of the surgeon console, the patient cart, which holds the articulated arms, and the imaging system. Shown in the figure is the surgeon console, with the surgeon looking into the console viewer, and the da Vinci Si patient cart with Single-Site instruments. (©2015 Intuitive Surgical, Inc.)

community.¹⁶ da Vinci robot surgeries have been associated with a decreased length of stay, lower transfusion rate, and lower in-hospital death rate, but some studies have shown that robot-assisted surgeries are associated with increased cost when compared to laparoscopic and open surgeries.¹⁴

The main components of the da Vinci system are a master console and a floor-mounted slave. The slave consists of three to four robotic arms that are each capable of manipulating an instrument with three DOF. The master console is equipped with two cameras that together provide a 3D view of the surgical field.¹⁷ The slave is controlled via the master/slave manipulator through the use of finger cuff telemanipulators. The master console was created with the surgeon's needs in mind, as it has adjustable finger loops on the telemanipulators, an adjustable intraocular distance, and padded head rest and arm bars.¹⁸

The instruments make this surgical system unique—they have seven DOF, mimicking the movements of the human wrist, and have tremor filtration.¹⁷ There are a few hurdles that have limited the advancement of this technology, including the cost of the robot and instruments, lack of haptic feedback, size of the system, and inability to quickly switch instruments during a procedure.^{17,19}

ROBODOC (THINK Surgical, Inc., Fremont, California) is a bone resection device used in orthopedic surgery. While other early surgical robots were used mainly in an assistive capacity, the ROBODOC was designed as a semiautonomous system to increase the accuracy of femoral implants and reduce the incidence of perforation and fracture of the femur in revisional hip replacement surgeries.²⁰ ROBODOC was developed jointly in 1990 by Integrated Surgical Systems and IBM. The ROBODOC design is based on a customized version of a Selective Compliance Assembly Robot Arm (SCARA) industrial robot.²¹ ROBODOC is a five-axis robot with haptic feedback sensors, making it possible to implement manual guidance, tactile search, and safety checking, and to adapt the cutter feed rate.²² Autonomous ROBODOC actions are programmed preoperatively with the Orthodoc Presurgical Planner (ORTHODOC) computer program.²¹ The surgeon places two guide pins on the patient's femur, and a CT scan with guide pin locations is loaded into the ORTHODOC software, creating a 3D model of the bone.²³ Surgical procedures are preprogrammed into ROBODOC, but each step must be manually approved throughout the procedure.^{21,23} There have been reports of complications with the ROBODOC, including aerosolization of bodily fluids and tissues, heat damage, and procedure stop due to bone motion during cutting.^{24–27} ROBODOC received FDA approval in 2008 and is also sold in Europe, Asia, and other regions.³

The Robotic Arm Interactive Orthopedic (RIO) System (MAKO Surgical Corp., Ft. Lauderdale, Florida) is another robot designed to assist in the placement of orthopedic devices in UKA. Studies comparing RIO procedures to conventional UKA found the RIO procedures had improved positioning and soft tissue balancing, decreased variance, and better alignment than conventional surgery.^{28,29} RIO is

a semiautonomous system controlled by the surgeon, and it has both auditory and haptic feedback. The RIO software also uses presurgical CT scans to confine the area to be cut, thus limiting variability and undesirable bone loss. The RIO was approved for use by the FDA in 2005, and as of 2013 had been used for over 23,000 surgeries worldwide.^{30,31} The major difference between the ROBODOC and the RIO systems is that the ROBODOC operates autonomously, and the RIO is surgeon guided. Both systems have been shown to improve the accuracy of implant placement.^{28,29}

SURGICAL ROBOTICS IN DEVELOPMENT

There are several robots designed for use in minimally invasive surgery in clinical trials, including the MiroSurge, EndoSAMURAI, and SurgiBOT. MiroSurge is under development by Deutsches Zentrum für Luft-und Raumfahrt (Cologne, Germany), and this system can be used for both minimally invasive as well as open procedures.^{32,33} The robot manipulators have seven DOF, have haptic feedback sensors, and are primarily teleoperated, but they can be manually positioned as well.³³ Typically, three MIRO arms are used: two for guiding the instruments and one for the endoscopic camera.³³ The surgical system is versatile because of the many locations to mount the arms and multiple modes of control.³⁴

The EndoSAMURAI (Olympus, Tokyo, Japan) is a prototype endoscopic platform.^{35,36} The system is composed of a laparoscopic workstation and a more traditional endoscopic component.³⁶ The endoscopic component can both irrigate the lens and provide air insufflation.³⁵ The platform contains a traditional operating channel and two hollow, steerable arms, which have five DOF and are connected to the endoscope.³⁶ The surgical instruments can be easily exchanged in the hollow arms, which allows for a variety of tasks to be completed, including hemostasis, coagulation, grasping, tissue cutting, retreating, and suturing.³⁶ The ability to use commercially available endoscopic instruments also means operative costs can be reduced.³⁵ EndoSAMURAI may be more successful in performing intraperitoneal procedures because the surgeon is able to manipulate the arms outside of the normal scope, increasing the triangulation of the instruments.^{35,36} While there are many advantages to this device, a few limitations should be addressed, such as arm length and the suboptimal orientation of the instruments relative to the optics.³⁵

The SurgiBot (Transenterix, Durham, North Carolina) is a single-incision robotic surgery system consisting of flexible instruments controlled by the surgeon.³⁷ The advantages of the SurgiBot include strength of manipulation, improved 3D vision and ergonomics, and precision movement with scaling. Compared to the systems currently available, the SurgiBOT system is less expensive, allows for internal triangulation, and allows the surgeon to be next to the patient.³⁸ This patient-side, minimally invasive device is unique because it may allow underserved populations to

utilize surgical robots without the large investment needed to acquire current devices.³⁸

Miniature *in vivo* robots are a new area of surgical development. These robots are designed for insertion into the peritoneal cavity through a natural orifice or a single incision, providing a novel approach for addressing the constraints of single-incision laparoscopic surgery (SILS) and natural orifice transluminal endoscopic surgery (NOTES). These devices can be used inside the peritoneum without the typical constraints of the access point. Miniature robots can provide the surgeon with a repositionable visualization platform using peritoneum-mounted or mobile camera robots. One single-incision robot currently under development at the University of Nebraska has been successfully used in porcine procedures, including cholecystectomy, colectomy, and tissue biopsy (**Figure 119.3**).^{16,38–40} This robot consists of two arms with six DOF and interchangeable end effectors, including monopolar and bipolar cautery, graspers, and needle drivers.⁴¹ This surgical robot is controlled by a prototype interface with video imaging, two controllers, and a foot pedal, with the movements of the surgeon's hands on the interface being directly mirrored by the robot. This robot utilizes standard two-dimensional laparoscopic as well as a prototype 3D camera for imaging. Triangulation of the two robot arms is achieved with the imaging source centered between the robotic arms. The motors that power movement are located in the arm joints, which allows for a significant reduction in the size.⁴² In experimental testing using a live porcine model, this robot successfully completed a cecotomy in approximately 30 minutes.³⁹ This miniature robot has a much smaller footprint than currently available surgical devices and will potentially be more affordable, making it available to a wider range of facilities.



Figure 119.3 Miniature *in vivo* surgical robot, single-incision robot prototype. (From Zhang X et al. *Stud Health Technol Inform* 2011;163:740–2.)

FUTURE DIRECTION OF SURGICAL ROBOTICS

Early robots mainly functioned as positioning guides and were also designed to increase the precision of repetitive tasks, while current robots are in fact telemanipulation machines allowing the surgeon to guide instruments and motion that is mirrored from the control that the surgeon is using. This allows for a computer-aided approach to surgical manipulation and leaves open the possibility for automated function augmentation of visualization and other computer enhancements. While current technology is robust, there is little competition in the market for new devices and applications. This limits entry of devices into the market as well as creates barriers to novel technological approaches. Automation is one area where other industrial applications have significantly outpaced medical capabilities. It is clear that the goal of surgical robotics needs to be more patient centered and focus on patient safety and disruptive technology for common surgical problems. The monopoly that exists in surgical robotics must be disrupted so the high barrier to entry can be alleviated.

One area of robotic application is the use of NOTES and SILS entry to perform complex gastrointestinal procedures. This technique remains a significant challenge because of physical constraints of sending a device deep into the abdominal cavity, sometimes through up to 30 feet of intestine, for surgical manipulation. Only technological advances can make this a true possibility. Continued developments in robotic technologies promise to provide an improved platform for intuitive visualization and dexterous tissue manipulation to complete procedures using these less invasive approaches.

Robots of the future will likely be much more autonomous than the current machines, and almost certainly smaller, mass produced, and capable of tasks not possible with today's technology. Future robots will need to enhance and enable surgical procedures that are presently too risky or are too highly variable, leading to significant problems for surgeons attempting these complex tasks. Just as the da Vinci robot ushered in the age of intracorporeal suturing, so will robots of the future bring new capabilities.

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Essays on the future of endoscopic surgery: Redefining, future training, and credentialing pathways

AURORA D. PRYOR

As anyone who is engaged in the practice of minimal access surgery is aware, we have seen a myriad of changes in the last decade. Many of these novel approaches are presented in this book. The barriers between surgeon and gastroenterologist have continued to blur, and patients have options for treatment with a variety of less invasive approaches. As these techniques continue to evolve, we need to ensure that our medical providers are delivering high-quality patient care. We need to ensure that training, credentialing, and transparency to patients remain at a high level as we transition from more traditional approaches.

Training in general surgery has historically focused on big surgery and large incisions. As minimal access surgery has evolved, however, surgery is now done for a large number of procedures with small incisions or even transoral/endoscopic approaches. General surgeons continue to perform the vast majority of screening endoscopy cases in the country, and basic training must result in graduating surgeons competent to perform these procedures. In addition, training in upper gastrointestinal surgery now needs to include interventional endoscopy techniques for primary therapy as well as complication management techniques, such as dilation and stenting. This training may be nested within core general surgical training or evolve into a specialty curriculum as our training paradigm evolves. It is possible that the general surgeon of the future will focus only on common or emergent diseases, and specialists will address more complex pathologies.

There are active discussions among the leadership in general surgery to change residency training to a general

core and then a mandated fellowship or advanced training module. It is possible that general surgery as an all-encompassing specialty will be phased out. If that is the case, then we will need to be certified as disease-specific practitioners: foregut surgeons, bariatric surgeons, colorectal surgeons, etc. We must ensure that training in each of these areas is robust enough that we can offer our patients a full breadth of care options for their underlying disease. We will also continue to see blurring between the lines of gastroenterology and surgery.

Training and credentialing in new procedures for the practicing physician must also be considered. As physicians choose to adopt new techniques, they should be assessed for underlying minimal expectations in their current clinical capabilities, should undergo defined training specific for the new technique, possibly have proctoring for a new procedure, and at a minimum undergo review of initial outcomes. Credentials for a new procedure should also require surgeons to disclose the new or novel nature of the procedure to patients to ensure that they understand the surgeon's capability with this technique.

It is also important to track procedural performance to ensure optimal outcomes. Surgeons should also not maintain credentials for a procedure that they do not routinely perform. Peer review or observation may be a critical aspect of ongoing performance evaluation and should be included in recredentialing. Outcomes tracking and quality improvement programs should be required for all proceduralists in the future.

Despite systems to ensure safe adoption of new technologies into practice, there will remain questions on

applicability. What really constitutes a practice change that requires new training and credentialing? Do we need to disclose when we change suture types or try a newer version of a surgical stapler? Do we need training to switch vendors for our energy devices? Despite excellent safeguards and

planning, there will be innovations without clear adoption pathways. These technologies will require that we as physicians monitor each other and our outcomes to ensure that we use both traditional and novel interventions to achieve the optimum outcomes in patient care.

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